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Volume 28
Number 358 *Breeding behavior at successive generations following hybridization in soybeans*

Article 1

December 1948

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Robert R. Kalton
*U.S.D.A.*

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Kalton, Robert R. (1948) "Breeding behavior at successive generations following hybridization in soybeans," *Research Bulletin (Iowa Agriculture and Home Economics Experiment Station)*: Vol. 28 : No. 358 , Article 1.
Available at: http://lib.dr.iastate.edu/researchbulletin/vol28/iss358/1

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December, 1948 Research Bulletin 358

# Breeding Behavior at Successive Generations Following Hybridization in Soybeans

By Robert R. Kalton

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

FARM CROPS SUBSECTION

AGRONOMY SECTION

UNITED STATES REGIONAL SOYBEAN LABORATORY
DIVISION OF FORAGE CROPS AND DISEASES
BUREAU OF PLANT INDUSTRY, SOILS AND AGRICULTURAL ENGINEERING
AGRICULTURAL RESEARCH ADMINISTRATION
UNITED STATES DEPARTMENT OF AGRICULTURE
Cooperating

AMES, IOWA

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## SUMMARY

1. Bulk $F_2$, $F_3$ and $F_4$ populations of 25 soybean crosses were grown in replicated trials in successive years and evaluated for seed yield, date of maturity, plant height and lodging resistance in comparison with three of the parental varieties.

2. The bulk populations of the crosses differed considerably in mean agronomic performance in each generation. Differences in mean height, maturity and lodging resistance among the crosses remained relatively consistent from generation to generation, indicating that one bulk generation test would have sufficed for the evaluation of these characters.

3. Yield differences among the 25 bulk crosses were not consistent. Although some crosses were high or low in yield performance in each bulk test, others varied considerably in yield from year to year. Consequently, it would have been difficult to detect and eliminate the poorer yielding bulk crosses on the basis of results from a single test.

4. Yield differences between parental varieties were a poor indication of bulk population yield performance of crosses in the early segregating generations.

5. Mean agronomic performance in the bulk population trials was not indicative of differences between crosses in the extent of segregation for factors conditioning maturity, height, lodging resistance and seed yield.

6. Two of the highest and two of the lowest yielding crosses were selected on the basis of their yield performance in bulk population trials for a study of breeding behavior at successive generations by the use of the pedigree method.

7. Two spaced $F_1$ plant studies showed that the extent of heterosis for seed yield among these four crosses in comparison to Richland, the common parent, was not associated to any appreciable degree with differences in subsequent bulk population or pedigree yield performance.

8. Average plant height and maturity differences among the four crosses in the $F_1$ generation in relation to the common parent persisted in all advanced generation tests.

9. Plant height and maturity measurements made on spaced $F_2$ plants in each cross provided a relatively good estimate of average progeny performance for the same characters in $F_3$ and $F_4$ generations.

10. Seed yield measurements made on spaced $F_2$ plants were of little value in predicting the yield potentialities of their $F_3$ and $F_4$ progenies.

11. Replicated tests of progenies of 77 randomly selected $F_2$

plants in each cross indicated a high degree of heterozygosity for factors conditioning each agronomic character studied.

12. Results of replicated progeny tests of five randomly selected $F_3$ plants in each of 15 $F_3$ families per cross also showed that there was little homozygosity in the $F_3$ generation for factors conditioning maturity, height and lodging resistance.

13. Selection for differences in seed yield among $F_3$ lines did not seem warranted on the basis of results obtained in the $F_4$ generation.

14. Breeding behavior for lodging resistance appeared somewhat less consistent than breeding behavior for plant height and maturity among the four crosses.

15. All results appeared to justify the conclusion that soybean varieties differ widely in combining ability for factors determining the agronomic characters studied in this investigation.

16. Neither the bulk nor the pedigree method of early generation testing for yield, as used herein with four soybean crosses, was very reliable for estimating their yield potentialities, at least before the $F_4$ generation.

17. A strong and consistent positive association was observed between maturity and plant height in the $F_2$ to $F_4$ generations of all crosses in the pedigree study. These data indicated that selection for a combination of tall early plants would have been difficult.

18. Although maturity and plant height generally were positively associated with yield, the degree of relationship was not sufficiently consistent to indicate that desirable combinations of these characters could not have been found in the segregating populations of the four crosses.

19. The degree of association between lodging resistance and yield in $F_3$ and $F_4$ generations of the pedigree study was too small to be of significance.

20. Several reasons were postulated for the differential reaction of soybean crosses, as compared with small grain crosses, to methods of early generation testing for yield.

# Breeding Behavior at Successive Generations Following Hybridization in Soybeans[1]

By Robert R. Kalton[2]

Extensive breeding investigations with soybeans in this country have been under way for only a relatively short period of time. Breeding work was at first confined primarily to introduction and selection, but it was soon realized that the possibilities for continued improvement with these practices were definitely limited. Consequently, during the last 10 or 15 years, hybridization has rapidly supplanted these procedures as the principal means for obtaining new and improved varieties.

Methods of handling segregating populations of crosses in such self-pollinated crops as wheat, oats, barley and flax now are fairly well standardized. Practices involve various modifications of the pedigree method, the bulk method or a combination of the two. An advantage of the pedigree method is that it enables the investigator to conduct inheritance studies of characteristics in which the parents differ. The principal advantages of the bulk method are cheapness in cost and opportunity to conduct replicated bulk yield tests as early as the $F_2$ generation. Early generation yield testing with the pedigree method, on the other hand, is limited or practically impossible in certain crops because of the scarcity of seed produced on individual plants and the high cost of testing large numbers of lines in replicated tests. Segregating populations of soybean crosses are admirably adapted for breeding by either of the two methods, as comparatively large seed yields on spaced individual plants make it possible to conduct pedigree yield tests as early as the $F_3$ generation. Replicated tests for evaluation of agronomic potentialities of soybean crosses in early segregating generations following hybridization, therefore, can be used with either the bulk or the pedigree method of breeding.

Available evidence indicates that replicated tests of $F_2$ and $F_3$ populations of wheat and barley crosses may be of value in estimating yield potentialities of such crosses. Similar evidence of the merits of early generation testing for yield and other agronomic

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[1]Project 719 of the Iowa Agricultural Experiment Station. The author wishes to express his sincere appreciation to Dr. I. J. Johnson for many constructive suggestions and criticisms offered during the course of these investigations and in the preparation of this manuscript. He also is indebted to Drs. M. G. Weiss and C. R. Weber, who, in addition to making valuable suggestions, grew several of the early generations of the crosses used in this study. P. G. Homeyer and W. T. Federer were very helpful in the statistical aspects of the investigations.

The material presented in this bulletin represents a revision of a thesis of the same title which was submitted by the writer to the Graduate Faculty of Iowa State College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in June, 1947. A complete copy of the thesis is on file in the Iowa State College Library.

[2]Formerly Research Associate, Farm Crops Subsection, Iowa Agricultural Experiment Station, and Agent, Division of Forage Crops and Diseases, United States Department of Agriculture, now Associate Agronomist, Texas Research Foundation, Renner, Texas.

characters in soybean crosses is not available, as yet, in any substantiating amounts. There is a need, therefore, for experimental data on such practices, as they pertain to the handling of segregating populations of crosses in this crop. The investigations reported herein were conducted to obtain additional information relative to this problem. In this study the agronomic performance of several different soybean crosses was measured at the first four generations following hybridization. Both the bulk and the pedigree methods were used in these evaluations. It was thought by so doing that at least partial answers might be obtained to some of the questions concerned with the possibilities of early generation testing in soybean crosses. A few of the more salient of these questions follow:

1. Are measurements made on spaced $F_1$ plants in different crosses of any value in predicting the agronomic performance of subsequent segregates?
2. Are differences in the mean agronomic performance of bulk populations of crosses, as shown by replicated trials in the $F_2$ generation, substantiated by similar bulk tests in $F_3$ and $F_4$ generations in the following years?
3. Is there any correlation between the agronomic characteristics of individual $F_2$ and $F_3$ plants and their progeny means in succeeding generations?
4. To what extent is segregation for factors conditioning yield, maturity, height and lodging resistance among $F_2$ and $F_3$ plants in different crosses indicated by replicated tests of their progenies in the next generation?
5. Are there sufficient differences among $F_4$ progenies to warrant selection for yield in the parental $F_3$ lines?
6. How do the bulk and the pedigree methods of handling segregating populations of soybean crosses compare with each other in the evaluation of agronomic differences in early generations following hybridization?

The potential value of early testing in soybean crosses depends to no small extent on the nature of the answers to these and related questions. Consequently, they are given consideration wherever possible in the presentation and discussion of the results obtained in these experiments.

## REVIEW OF PERTINENT LITERATURE

Hayes and Immer (8) classify as naturally self-pollinated those crops which generally show less than 4.0 percent cross-pollination and include soybeans in this group. Actual experimental evidence indicates that the amount of natural crossing in this crop is considerably less than 4.0 percent. On the basis of observations made on segregating progenies of plants produced from off-colored seeds found in a bulk lot of soybean seed, Piper and Morse (18) postulated that the amount of natural crossing was small—possibly 0.5 percent. In the same study it was found that bagged and caged plants set seed as well as non-bagged and non-caged plants, thereby indicating complete self-fertility. In an experiment specifically designed to test the percentage of cross-pollination Woodworth (29) found 0.16 percent natural crossing. Similar studies by Garber and Odland (4) showed 0.14 percent natural crossing one year and 0.36 percent the next. These results all indicate that soybeans probably are better than 99.0 percent self-fertilized under natural conditions and, therefore, should be amenable to breeding procedures used with other self-pollinated crops.

Hybridization has been used commonly by plant breeders in the improvement of self-pollinated cereals. Generally, either the bulk or the pedigree method of handling segregating populations is employed following hybridization. The essential features and a general order of procedure for each method have been outlined by Hayes and Immer (8) and by Love (15). In this country the pedigree method has been used to a much greater extent than the bulk method, and numerous examples of the successful use of the former have been cited. A number of these were illustrated by Hayes and Immer (8). Florell (3), on the other hand, employed the bulk method with a number of wheat crosses in California with good success.

A modification of the bulk method tried by several investigators is the growing of bulk populations of a mixture of several crosses in large lots each year. It is assumed that this modification will allow for extensive segregation and recombination of factors conditioning the desired characters and for elimination of weak undesired types in the bulk populations by natural selection. Adair and Jones (1) grew three such mixtures of rice crosses at one location in Texas, one in California and one in Arkansas for each of 8 years, starting with the $F_3$ generation. In the ninth year a sample of seed from each bulk lot was grown at Stuttgart, Arkansas, and studied for the survival of desirable genotypes. Although the proportions of different types varied in the lots from the three locations, all bulk lots contained enough desirable agronomic types for satisfactory selection purposes. Harlan, Martini and Stevens (5) grew bulk populations of 379 barley crosses for seven generations in separate rows to maintain the identity of each cross. On the basis of average yields of each cross during this period single plant selections were made in space-planted plots in the eighth generation. In all, 2,921 selections were made with more taken from the higher than from the lower yielding crosses. Simultaneously, an equal number of plant selections was made in a space-planted plot of a composite mixture of all crosses which had been advanced to the same generation. All selections were then tested in non-replicated rows in the next generation with appropriate check varieties. It was found that yields of the bulk crosses during the preselection period provided a good indication of the yield performance of selections made therefrom. Selections made from the composite mixture of crosses, however, were as high in average yield as selections made from the pedigree crosses. The results were considered as justifying the elimination of lower yielding crosses on the basis of their non-replicated yield performance during the segregating generations before selection is practiced.

Other small grain breeders also have investigated the possibilities of yield testing bulk populations of crosses in early generations following hybridization. In replicated trials of bulk populations of six wheat crosses during the $F_2$ and $F_3$ generations Harrington (7) found considerable differences in yield among the crosses. Moreover, replicated tests of lines selected from these crosses in $F_6$ to $F_8$ generations substantiated their early generation yield performance. The use of these tests to evaluate crosses for such characters as milling and baking quality, disease resistance, etc., however, was not considered feasible. Immer (11) compared bulk populations of six barley crosses in replicated trials in $F_2$, $F_3$ and $F_4$ generations and observed that some crosses were consistently higher in yield than others. The average performance of the same crosses in a space-planted $F_1$ test, however, did not agree with their bulk yield performance in drilled plots in succeeding generations. It was suggested that such tests might be used to eliminate poorer yielding crosses in early generations following hybridization since they would contain fewer high-yielding genotypes than higher yielding crosses.

Another method suggested as a means for predicting the potential value of any given cross is an evaluation of the characteristics of a number of $F_2$ plants. In the wheat cross Marquillo x Marquis, Harrington (6) grew an $F_2$ population of nearly 40,000 plants. After 5 years of rigid pedigree selection for desired characters only six lines of questionable value were retained, even though the cross originally promised a combination of the best features of the two parents. An analysis of a random sample of several hundred $F_2$ plants from this cross gave a similar prediction as to the limited possibilities for obtaining the desired recombinations. Some characters were successfully predicted by the $F_2$ analysis. They were: rust resistance, plant height, maturity and seed appearance. The average seed yield of all $F_2$ plants in comparison with average parental plant yields, however, did not correctly predict the yield performance of subsequently selected lines. Immer (12) measured the means and variances of seed yields of four $F_2$ crosses and four varieties of barley in a replicated space-planted test. Mean yields of varieties and mean yields of $F_2$ crosses were both significantly different among themselves. Variance of seed yields per plant within plots, however, was not much greater for the $F_2$ crosses than it was for the comparable parent varieties. Consequently, it was concluded that variation in seed yields of single plants in space-planted progeny rows was determined almost completely by environmental factors.

In a replicated space-planted study of the parents and $F_1$ and $F_2$ generations of three intraspecific crosses in cotton, Hutchinson, Panse and Govande (10) also found that the environment was responsible for the greatest proportion of the total variance of agronomic characters among $F_2$ plants. They concluded that single plant selection for staple length, ginning percentage and certain other characters in progeny rows in $F_2$ was likely to be inefficient. This experiment was continued by Panse (16), who grew replicated progenies of a sample of $F_2$ plants in each cross in the $F_3$ generation and studied them for staple length. Regression coefficients of mean staple length of $F_3$ progenies on $F_2$ plants were highly significant in two of the three crosses. He considered that it would be advantageous, therefore, to select individuals whose staple length exceeded the mean plot value in replicated tests of spaced $F_2$ plants.

Early testing of inbred lines of corn also is, in a way, comparable to early generation testing of crosses in self-pollinated crops. The two methods are similar in that they are both used in an attempt to estimate the genotypic value of subsequent segregates. Probably the first experimental evidence favoring early testing of corn inbreds was that obtained by Jenkins (13). He measured the effect of inbreeding upon hybrids made after successive generations of selfing and found that the lines apparently acquired their individuality as top cross parents relatively early in the inbreeding process. In another study utilizing top cross performance as a measure of combining ability Jenkins (14) obtained results that indicated only a limited segregation for factors conditioning yield prepotency among individual plants within seven $S_1$ lines. Sprague (21) also obtained substantiating evidence in favor of early testing of corn inbreds. He found top cross yields of $S_1$ plants, representing the high 10.0 percent of an $S_0$ top cross yield distribution of 167 plants from a stiff-stalk synthetic, equivalent to yields of the selected parents. In a later test three $S_3$ lines from this selected group gave a better average yield performance in single crosses than several standard commercial inbreds. Sprague and Bryan (22) obtained evidence of significant segregation for factors conditioning yield prepotency, lodging and disease resistance in both $F_3$ and $F_4$ lines of corn. In top cross tests of $F_4$ lines, however, the $F_3$ families showed considerably greater variation for these characters than their $F_4$ progenies. Singleton and Nelson (19) failed to find any correlation between combining ability in the $S_0$, $S_1$ or $S_2$ generations and the $S_3$ generation in inbred lines of sweet corn. Moreover, they were able to increase combining ability (for yield) from the $S_0$ to the $S_3$ generation by intensive selection.

The adaptability of soybean crosses to early generation testing procedures depends to a considerable extent on breeding behavior for desired characters at successive generations following hybridization. Despite the large number of crosses that have been made between varieties and strains of this crop in recent years there is little information pertaining to this subject. Both Wentz and Stewart (28) and Woodworth (30) found indications of hybrid vigor for seed yield and plant height in a few $F_1$ and parental plants in each of several soybean crosses. Veatch (24) also obtained evidence of heterosis in the $F_1$ generation. He went a step further, however, and studied several of his $F_2$ populations in comparison with the parents. Although the results indicated transgressive segregation for seed yield and height among the $F_2$ plants of each cross, none of the $F_2$ populations was significantly above the higher yielding parent in mean seed yield per plant, and all were between the parents in average plant height. In a similar study Stewart (23) obtained essentially the same results. None of these investigators attempted to relate their $F_1$ and $F_2$ results with breeding behavior in subsequent generations.

Probably the most extensive information pertaining to hybrid vigor in soybean crosses was that presented by Weiss, Weber and Kalton (27). In a replicated plant test of 17 $F_1$ crosses and their parents in the greenhouse they obtained higher average seed yields per plant than in either parent in 16 of the crosses. In an $F_1$ field test of the same crosses all exceeded the higher yielding parent in average seed yield per plant. All $F_1$ crosses were consistently between the parents in average date of maturity, average height and average lodging resistance per plant in the same test. In $F_2$ to $F_5$ generations both the bulk and pedigree methods of breeding were used to test the agronomic performance of the same crosses. Advanced generation results indicated that the degree of heterosis for seed yield, as determined on spaced $F_1$ plants, was of little or no value in estimating the yield potentialities of subsequent segregates from a cross. $F_1$ data on other agronomic characters was not correlated with breeding behavior in $F_2$ and later generations.

Average plant measurements for seed yield and date of maturity on replicated, spaced $F_2$ plant populations of the 17 crosses were indicative of cross differences in later generations in respect to these characters. Maturity readings on spaced $F_2$ plants were highly correlated with mean maturities of their progenies in $F_3$, but similar associations for yield were of a considerably lesser magnitude. Replicated tests of selected $F_3$ and $F_4$ lines, each of which descended from single $F_2$ and $F_3$ plants, respectively, resulted in good estimates of future expectations for maturity, height and lodging resistance. Replicated pedigree-progeny tests for seed yield in early segregating generations, however, were noticeably influenced by seasonal differences. As a result, evaluation for this character did not appear justified before possibly the $F_4$ generation. In another phase of the same study bulk populations of each of the 17 crosses, including bulk $F_2$ to $F_5$ generations, were grown together in one replicated test and their mean seed yields, maturity dates, lodging scores and plant heights determined. In this test significant interactions were obtained between generations and crosses in the analysis of variance for each character. Consequently, no one bulk generation sufficed to evaluate accurately the relative differences in agronomic performance among the crosses. Average height and the degree of lodging resistance of the bulk populations were useful in predicting the performance of subsequent selections for these characters. This was not true to any appreciable extent for average seed yield and date of maturity.

Patel (17), in an attempt to determine if high yielding $F_3$ plants had high yielding progenies, grew duplicate progeny rows of 249 $F_3$ plants in the $F_4$ generation and measured them for seed yield. Three different soybean crosses were represented in the study. The results showed a definite tendency for high-yielding $F_3$ plants to have high-yielding progeny rows in the next generation. Henson (9) bulked the seed from each of the 25 highest yielding $F_4$ rows in each of the three crosses and used it to plant a replicated yield test in the $F_5$ generation. Considerable differences in seed yield among the strains were obtained in this test. Moreover, it was found that average yields of selections in the $F_5$ generation were definitely related to yields of their parental $F_4$ rows of the previous year. One of the best of these bulk $F_5$ strains was continued in bulk until $F_7$, at which time it was grown in a space-planted plot. Weatherspoon (25) selected 237 plants in this plot, measured them for seed yield, and planted a 5-foot progeny of each the next year. These progeny rows were measured for seed yield and their seed in turn used to plant a replicated yield test of all strains in the $F_9$ generation. Correlations for seed yield among the three successive generations of the 237 lines were as follows:

$F_7$ plant and $F_8$ progeny row, $r = .016$
$F_7$ plant and $F_9$ mean yield, $r = .128$
$F_8$ progeny row and $F_9$ mean yield, $r = -.003$

This decided lack of association was considered as indicating the uselessness of selecting for yield on a single plant or progeny row basis.

The results of the replicated $F_9$ test of the 237 strains were analyzed by Weatherspoon and Wentz (26). The analyses of variance showed that the strain means differed significantly for plant height, number of nodes per plant, number of pods per node, number of seeds per pod, percentage of abortive seed, seed size and seed yield. As these strains all originated from the same $F_3$ plant, the results indicated little homozygosity in $F_3$ for factors conditioning the characters studied. Davis (2) selected 37 of the highest yielding $F_9$ lines for further testing in replicated trials. He found significant differences in mean yield among the strains in both 1933 and 1935 but did not evaluate their relationship with results of previous generations.

## MATERIALS AND METHODS

During the period from 1936 to 1940 many soybean varieties and plant introductions were tested at various locations in Iowa. Many of these strains were discarded on the basis of their poor performance in these tests. A few, although not significantly better in performance than the varieties in commercial production, were sufficiently promising in one or more features to merit use as parents in a hybridization program. Since most of those selected as parental material for crosses were lacking in lodging resistance, they all were crossed to the Richland variety. Richland was selected as the common parent because of its outstanding lodging resistance, good seed yield, satisfactory oil content of the seed and relatively early maturity. In all, 25 different crosses were made in the summer of 1941. The $F_1$ through the $F_4$ generations of these crosses constituted the material studied in this investigation.

The $F_1$ generations were grown in 1942. In each cross the $F_1$ plants were grown between the two parents in 32-inch rows. Within rows the plants of parents and $F_1$ generations were spaced 1 foot apart. By this method of planting it was possible to compare average seed yields per plant of $F_1$ of each cross with either parent and the mean of the two parents. Four of the crosses were remade in 1945 and tested again in 1946. These crosses were as follows: Mukden x Richland, Manchuria 13-177 x Richland, P. I. 79885 x Richland and P. I. 89009-2 x Richland. In the cross Mukden x Richland, in 1942, only adjacent competitive plants of parents and $F_1$ were measured for seed yield. In the other three crosses all available plants of each were harvested for yield determinations, irrespective of competition. Data on agronomic characters other than yield were not taken in 1942. In 1946, however, maturity and height were evaluated in addition to yield. The manner of planting was changed in 1946 so that plants of both parents and $F_1$ were alternately spaced in each row. Plants within the row were spaced 8 inches apart. This method resulted in a total separation of only 16 inches between the three plants in each paired comparison. Although this reduced the number of competitive comparisons, it helped to decrease the amount of soil heterogeneity.

Seed harvested from all $F_1$ plants in each of the 25 crosses was composited and used to plant a bulk population yield test of the $F_2$ generation in 1943. In addition to the bulk crosses, Lincoln and Richland were entered twice and Mukden once as check varieties to give a total of 30 entries in a randomized complete block design with six replications. Each replication of an entry consisted of a single, drilled 18-foot row which was trimmed to 16 feet just before harvest. Another portion of the bulked seed of each cross was planted in a separate plot for generation advancement. Using the same procedures, yield tests of bulk $F_3$ and bulk $F_4$ generations were grown in 1944 and 1945, respectively. A small test of the bulk $F_3$ generation of four crosses selected for special study was grown in 1945. In that test Lincoln, Richland and Mukden each were entered once as check varieties in a randomized complete block design with six replications. A 32-inch row spacing was used in the 1943 and 1944 bulk tests and a 3-foot spacing in the 1945 tests. Measurements were taken on the following agronomic characters of each cross: yield of seed, maturity, height and lodging. The consistency in expression of these characters by the bulk populations of the 25 crosses at successive generations in consecutive years was evaluated by correlations.

On the merits of their performance in the bulk $F_2$ and $F_3$ yield tests in 1943 and 1944, respectively, the two highest and two of the lowest yielding bulk crosses were selected for investigation on a pedigree basis. The two highest yielding bulk crosses were Mukden x Richland and Manchuria 13-177 x Richland. The two low-yielding bulk crosses were P. I. 79885 x Richland and P. I. 89009-2 x Richland.

A space-planted plot of the $F_2$ generation of these four crosses was grown in 1944. Seed used for this planting was remnant seed of composited lots harvested from $F_1$ plants in 1942. A random sample of 200 seeds from each cross was planted in a 32-inch row with a uniform spacing of 8 inches between plants within the row. Similar plots of Lincoln, Richland and Mukden also were included. In the fall of 1944 the first 100 consecutive competitive plants of each cross were tagged. Individual plant measurements were made on these plants for seed yield, maturity and plant height. Frequency distributions, means, standard deviations and coefficients of variation were calculated for each character using the data gathered from the plants in each cross and variety. These data provided estimates of the amount of variability for each character in $F_2$ of the crosses as compared with the parental varieties.

These four crosses were continued on a pedigree basis in the $F_3$ generation in 1945, when a yield test of the progenies of most of the $F_2$ plants in each cross was grown. The first 77 of the 100 $F_2$ plants which produced sufficient seed for planting the $F_3$ test were selected to represent each $F_2$ population. In addition, the two parents and the bulk $F_2$ and $F_3$ generations of each cross were included, giving a total of 81 entries per cross. The planting plan for each cross consisted of three replications of a 9 x 9 triple lattice. Each entry in a replication consisted of a single, drilled 8-foot row with each row spaced 3 feet apart. This test, hereafter called the $F_3$ line test, was designed so that not only differences between lines within crosses but also differences between crosses could be ascertained. This was accomplished by randomizing first by crosses and then by $F_3$ lines within crosses for each replication. Measurements were taken on seed yields, maturities, heights and lodging of the $F_3$ lines in the fall of 1945. Analyses of variance for each of the characters were calculated subsequent to harvest. Relationships between $F_2$ plants grown in 1944 and means of their progenies in the $F_3$ line test in 1945 were determined for each character by correlations.

A space-planted row of each of the 77 $F_3$ lines per cross was grown in a separate nursery in 1945. In the fall of that year, the first five plants in each row were harvested and threshed individually. Their seed was used to plant the $F_4$ line test in 1946. As it was not possible to test progenies of all $F_3$ lines, it was necessary to take a representative sample of the $F_3$ lines in each cross for continuing the study into the $F_4$ generation. This was done by first eliminating the extremely early and late $F_3$ lines in each cross, thereby minimizing a possible bias from positive correlations between maturity and yield. In this manner the number of $F_3$ lines in each cross was arbitrarily reduced to 60. They were then ranked according to yield from highest to lowest. As 15 lines appeared about the maximum that could be progeny-tested in each cross, the yield arrays were separated into 15 groups of four each. Using a random start from one to four for each cross, every fourth line thereafter was selected to make up the total of 15 lines per cross. Each $F_3$ line thus selected was represented in the $F_4$ test in 1946 by progeny of five $F_3$ plants.

In all, 75 $F_4$ lines (five $F_4$ lines for each of 15 $F_3$ lines) from each cross were grown in a randomized split plot design in 1946. Also included in the test were the parents and bulk $F_3$, $F_4$ and $F_5$ generations, thus making a total of 80 entries per cross. The design was such that three sets of differences for each agronomic character under investigation could be measured. These differences were those between crosses, between $F_3$ family progenies and between the five $F_4$ lines representing each $F_3$ family. Each $F_4$ line in the test was replicated three times with each replication consisting of a single, drilled 8-foot row spaced 3 feet apart. Each replication of the four crosses was randomized first on a cross basis, then on an $F_3$ family progeny basis for each cross and finally on an $F_4$ line basis. This planting procedure resulted in the greatest accuracy for evaluating differences between the $F_4$ lines of any $F_3$ family. Measurements were taken on the same agronomic characters in this test in 1946 as were taken in the $F_3$ line test in 1945. Relationships between $F_2$ plants in 1944 and means of their five descendant $F_4$ lines in 1946 were evaluated for each agronomic character by correlations. For the cross Mukden x Richland, the availability of $F_3$ single plant data enabled the calculation of a further correlation, that between $F_3$ plants and their $F_4$ line means.

A frequent subject for discussion among soybean breeders is whether or not a relationship exists among maturity, height, lodging and yield in segregating populations of soybean crosses. In order to obtain further information pertaining to this question, simple and partial correlations between certain of these characters were calculated from data obtained in pedigree tests of $F_2$, $F_3$ and $F_4$ generations in 1944, 1945 and 1946, respectively. Of the possible correlations, only those within each year were determined.

All tests in this investigation were conducted at the Agronomy Farm, Ames, Iowa. Methods used for evaluating each of the agronomic characters studied were as follows:

**Seed Yield**—all seed was dried to a uniform moisture before weighing. Plant seed yields were determined in grams. Plot yields were calculated on a bushels per acre basis.

**Maturity**—plants or plots were considered mature when 90 to 100 percent of the pods had turned brown and most of the leaves had fallen. Maturity was taken as number of days after August 31 when this stage was reached.

**Height**—plants or plots were measured in inches for average height from the ground to the highest point on mature plants.

**Lodging**—plots were assigned lodging scores which ranged from a score of 1, where most plants in the row were perfectly erect, to a score of 5, where most plants were prostrate.

Statistical and experimental procedures, as outlined in Snedecor (20) and Hayes and Immer (8), were used throughout the course of these experiments.

# EXPERIMENTAL RESULTS

## $F_1$ GENERATION SPACED PLANT STUDY

Assuming a judicious choice of parents, the first opportunity to measure the potentialities of any cross is in the $F_1$ generation. In a highly cross-pollinated crop such as corn, the performance of the hybrid is of primary importance and usually easy to determine. In self-pollinated crops, on the other hand, performance of the $F_1$ generation not only is difficult to determine but also is of questionable significance. The number of crossed seeds that can be obtained in such self-pollinated crops as wheat, oats, barley and soybeans is very limited in most breeding programs. This limitation decidedly impairs the accuracy of agronomic measurements made in the $F_1$ generation. Moreover, even if accurate $F_1$ information could be obtained, it might not necessarily be indicative of the consequences of segregation and recombination that result from continued self-pollination in subsequent generations. Experimental evidence on the latter point is not abundant, as most investigators have not related the performance of $F_1$ generations to that of segregates from the same crosses in advanced generations. In this study an attempt was made to obtain information on the $F_1$ generation of several soybean crosses and to relate this information to breeding behavior in subsequent generations.

### SEED YIELD

Although it is especially difficult to obtain large numbers of crossed seeds in soybeans, enough were produced in the crosses studied to make limited comparisons of certain agronomic characteristics in the $F_1$ generations with those of the parents. Measurements of yields were made in both 1942 and 1946 on a single plant basis. Mean seed yields in grams per plant for the $F_1$ generations of four soybean crosses as compared with those of the parents appear in table 1. The 1942 results with the cross Mukden x Richland were the most reliable because only adjacent competitive plants of $F_1$ and parents were used for determining yields. This cross also had the greatest number of plants. In the other three crosses in 1942, all $F_1$ plants and the parents in each cross were harvested from adjacent rows without respect to competition. However, the number of competitive and non-competitive plants was approximately the same for

TABLE 1. MEAN YIELDS IN GRAMS PER PLANT FOR $F_1$ GENERATIONS OF FOUR SOYBEAN CROSSES AS COMPARED WITH YIELDS OF PARENTS.

| Parent or hybrid | Number of plants | Grams per plant | Mean yield of parents | $F_1$ in percentage of: | | |
|---|---|---|---|---|---|---|
| | | | | $P_1$ | $P_2$ | Mean of parents |
| | | 1942 | Results | | | |
| Mukden | 42 | 67.7 | | | | |
| Mukden x Richland | 42 | 71.9 | 64.8 | 106.2 | 116.2 | 111.0 |
| Richland | 42 | 61.9 | | | | |
| Manchuria 13-177 | 20 | 56.5 | | | | |
| Manchuria 13-177 x Richland | 21 | 80.6 | 52.3 | 142.7 | 167 6 | 154.1 |
| Richland | 21 | 48.1 | | | | |
| P. I. 79885 | 13 | 67.7 | | | | |
| P. I. 79885 x Richland | 12 | 89.6 | 64 4 | 132.3 | 146.4 | 139.1 |
| Richland | 13 | 61.2 | | | | |
| P. I. 89009-2 | 27 | 52.0 | | | | |
| P. I. 89009-2 x Richland | 25 | 67.2 | 48.3 | 129.2 | 150.7 | 139.1 |
| Richland | 28 | 44.6 | | | | |
| | | 1946 | Results | | | |
| Mukden | 5 | 49.2 | | | | |
| Mukden x Richland | 5 | 43.0 | 41.5 | 87.4 | 127.2 | 103.6 |
| Richland | 5 | 33.8 | | | | |
| Manchuria 13-177 | 2 | 69.0 | | | | |
| Manchuria 13-177 x Richland | 2 | 60.0 | 54.3 | 87.0 | 151.9 | 110.5 |
| Richland | 2 | 39.5 | | | | |
| P. I. 79885 | 4 | 39.8 | | | | |
| P. I. 79885 x Richland | 4 | 58.3 | 43.4 | 146.5 | 124.0 | 134.3 |
| Richland | 4 | 47.0 | | | | |
| P. I. 89009-2 | 5 | 54.0 | | | | |
| P. I. 89009-2 x Richland | 5 | 55.0 | 44.6 | 101.9 | 156.3 | 123.3 |
| Richland | 5 | 35.2 | | | | |

the two parents and the hybrid so that the comparisons seemed worthy of inclusion. Only competitive plants were evaluated in each cross in 1946.

$F_1$ plants of all crosses produced a higher average yield per plant than the mean of the two parents in both years. It should be noted, however, that the amount of superiority varied considerably from cross to cross. In 1942, the $F_1$ generation of all crosses exceeded the higher yielding parent, while in 1946 this occurred with only two of the four crosses. Since Richland was a common parent, comparisons of $F_1$ plant yields with it were of interest. $F_1$ crosses Manchuria 13-177 x Richland and P. I. 89009-2 x Richland exceeded the Richland parent to the greatest extent in yield in both years. The $F_1$ cross Mukden x Richland produced the smallest average increase in yield over the Richland parent of the four crosses in 1942 and was second lowest in 1946. If $F_1$ yields were related to the possibility of obtaining high yielding segregates in later generations, the expectation would be that the cross Mukden x Richland would be the least promising of the four crosses from a yield standpoint.

TABLE 2. MEAN MATURITIES IN NUMBER OF DAYS AFTER AUGUST 31 FOR $F_1$ GENERATIONS OF FOUR SOYBEAN CROSSES AS COMPARED WITH MATURITIES OF PARENTS.

| Parent or hybrid | Number of plants | Mean maturity | Mean maturity of parents | $F_1$ expressed as days earlier (—) or later (+) than: $P_1$ | $P_2$ | Mean of parents |
|---|---|---|---|---|---|---|
| Mukden | 5 | 33.6 | | | | |
| Mukden x Richland | 5 | 32.2 | 31.1 | —1.4 | +3.6 | +1.1 |
| Richland | 5 | 28 6 | | | | |
| Manchuria 13-177 | 2 | 48.5 | | | | |
| Manchuria 13-177 x Richland | 2 | 39.0 | 40.0 | —9.5 | +7.5 | —1.0 |
| Richland | 2 | 31.5 | | | | |
| P. I. 79885 | 5 | 30.6 | | | | |
| P. I. 79885 x Richland | 5 | 31.2 | 30.2 | + .6 | +1.4 | +1.0 |
| Richland | 5 | 29.8 | | | | |
| P. I. 89009-2 | 4 | 37.0 | | | | |
| P. I. 89009-2 x Richland | 4 | 38.5 | 34 6 | +1.5 | +6.2 | +3.9 |
| Richland | 4 | 32.3 | | | | |

MATURITY

Mean maturities for $F_1$ of the four crosses as compared with maturities of the parents in 1946 are presented in table 2. The average maturity of $F_1$ plants was between the two parents in two of the crosses and slightly later than either parent in the other two. It seemed possible, therefore, that opportunities for securing segregates later than either parent in subsequent generations were greater with crosses P. I. 89009-2 x Richland and P. I. 79885 x Richland than with the other two crosses. As will be shown, this supposition proved to be true for the latter cross in advanced generations.

PLANT HEIGHT

Comparative measurements on plant height also were obtained in 1946 on a few parental and $F_1$ plants in each cross. These mean

TABLE 3. MEAN HEIGHTS IN INCHES FOR $F_1$ GENERATIONS OF FOUR SOYBEAN CROSSES AS COMPARED WITH HEIGHTS OF PARENTS.

| Parent or hybrid | Number of plants | Mean height | Mean height of parents | $F_1$ in percentage of: $P_1$ | $P_2$ | Mean of parents |
|---|---|---|---|---|---|---|
| Mukden | 5 | 45.4 | | | | |
| Mukden x Richland | 5 | 41.4 | 40.2 | 91 2 | 118.3 | 103.0 |
| Richland | 5 | 35.0 | | | | |
| Manchuria 13-177 | 2 | 47.0 | | | | |
| Manchuria 13-177 x Richland | 2 | 42.5 | 41.8 | 90.4 | 116 4 | 101.7 |
| Richland | 2 | 36.5 | | | | |
| P. I. 79885 | 5 | 26.6 | | | | |
| P. I. 79885 x Richland | 5 | 29.8 | 30.4 | 112.0 | 87 1 | 98.0 |
| Richland | 5 | 34.2 | | | | |
| P. I. 89009-2 | 5 | 26 6 | | | | |
| P. I. 89009-2 x Richland | 5 | 36.6 | 30.4 | 137.6 | 107.0 | 120.4 |
| Richland | 5 | 34.2 | | | | |

height measurements are shown in table 3. In only one of the four crosses, namely, P. I. 89009-2 x Richland, were $F_1$ plants taller on the average than either parent. In the other three crosses $F_1$ plants were intermediate to the parents in height. In light of these results it might have been expected that possibilities of finding segregates taller than either parent were greatest in the cross P. I. 89009-2 x Richland and less in the other crosses. Likewise, the opportunity for finding segregates exceeding Richland in height in cross P. I. 79885 x Richland seemed somewhat remote. As will be seen in later sections, these predictions actually were correct. However, it also will be shown that these observations made in the $F_1$ generation were not necessarily indicative of the extensiveness of segregation for plant height in later generations.

## BULK POPULATION TESTS

The simplest method of testing bulk crosses in a practical breeding program with self-pollinated crops is to grow successive generations in consecutive years. This procedure eliminates the necessity of maintaining seed stocks in storage for several years or the remaking and continued growing of successive generations so that several bulk generations can be tested in the same year. It also removes the undesirable consequences of differential seed viability resulting from storage. With a crop such as soybeans, however, this method has certain definite disadvantages. Soybeans are quite sensitive to damage from early frosts, especially when full-season adapted varieties are grown, and relative differences among varieties are known to vary considerably with environmental fluctuations due to seasonal and locality changes. Furthermore, in early segregating generations the proportions of early and late segregates in bulk populations of crosses may be altered by time of occurrence of the first killing frost in the fall. Consequently, these factors provide limitations to the breeding value of early generation testing of bulk crosses in soybeans, even though this procedure might actually be indicative of the potentialities of future segregates if testing could be carried out under uniform conditions.

### SEED YIELD

In this study bulk $F_2$, $F_3$ and $F_4$ generations of 25 soybean crosses were tested in successive years with three of the commercially important parental varieties included as checks. Table 4 shows the average seed yields and yield ranks of the crosses and the average seed yields of the varieties that were obtained. Lincoln was the highest yielding variety each year. Richland and Mukden were among the poorest yielding entries in each test except the bulk $F_4$ test in 1945, when they were near the midpoint of the yield array. As an average for the 3 years, Lincoln ranked first, Mukden second and Richland third in yield. Variety test plots at Ames over a period

TABLE 4. MEAN YIELDS IN BUSHELS PER ACRE AND YIELD RANKS OF BULK $F_2$, $F_3$ AND $F_4$ GENERATIONS OF 25 SOYBEAN CROSSES AND THREE CHECK VARIETIES GROWN IN SUCCESSIVE YEARS.

| Cross or variety | Cross number[1] | 1943 Bulk $F_2$ (Bu.) | 1943 Rank | 1944 Bulk $F_3$ (Bu.) | 1944 Rank | 1945 Bulk $F_4$ (Bu.) | 1945 Rank | 1943 to 1945 Average (Bu.) | 1943 to 1945 Rank |
|---|---|---|---|---|---|---|---|---|---|
| Dunfield x Richland | 1115 | 46.3 | 4 | 37.2 | 5 | 34.9 | 17 | 39.5 | 4 |
| Illini x Richland | 1315 | 45.2 | 8 | 35.8 | 15 | 33.3 | 23 | 38.1 | 18 |
| Mukden x Richland | 1415 | 48.1 | 1 | 37.1 | 7 | 37.0 | 2 | 40.7 | 1 |
| Richland x Mandell | 1512 | 44.5 | 13 | 34.7 | 17 | 35.5 | 14 | 38.2 | 14 |
| Richland x B. H. Manchu | 1516 | 45.4 | 6 | 34.1 | 21 | 35.1 | 16 | 38.2 | 14 |
| Richland x Mandarin 507 | 1517 | 42.3 | 20 | 31.1 | 25 | 35.7 | 8 | 36.4 | 23 |
| Richland x Linman 533 | 1518 | 44.9 | 11 | 36.9 | 8 | 36.1 | 7 | 39.3 | 7 |
| Richland x Wis. Manchu No. 3 | 1519 | 45.4 | 6 | 36.1 | 14 | 36.5 | 4 | 39.3 | 7 |
| Manchuria 13-177 x Richland | 2715 | 48.1 | 1 | 36.9 | 8 | 33.4 | 22 | 39.4 | 5 |
| L34R12 x Richland | 2815 | 47.4 | 3 | 37.2 | 5 | 35.6 | 9 | 40.1 | 2 |
| L6-12 x Richland | 2915 | 45.2 | 8 | 36.6 | 12 | 34.6 | 19 | 38.8 | 10 |
| Lincoln x Richland | 3015 | 45.2 | 8 | 34.6 | 18 | 36.7 | 3 | 38.8 | 10 |
| P. I. 30600-2 x Richland | 3115 | 43.4 | 15 | 39.2 | 2 | 35.6 | 9 | 39.4 | 5 |
| P. I. 65346 x Richland | 3215 | 41.3 | 24 | 37.9 | 3 | 37.8 | 1 | 39.0 | 9 |
| P. I. 68474 x Richland | 3315 | 42.6 | 19 | 34.4 | 20 | 34.9 | 17 | 37.3 | 21 |
| Richland x P. I. 68474-1 | 1534 | 46.3 | 4 | 34.6 | 18 | 35.6 | 9 | 38.8 | 10 |
| P. I. 79885 x Richland | 3515 | 42.3 | 20 | 34.1 | 21 | 33.1 | 24 | 36.5 | 22 |
| P. I. 88298 x Richland | 3615 | 43.0 | 17 | 37.4 | 4 | 35.2 | 15 | 38.5 | 13 |
| P. I. 89009-2 x Richland | 3715 | 41.6 | 23 | 33.0 | 23 | 31.7 | 25 | 35.4 | 25 |
| P. I. 91161 x Richland | 3815 | 44.8 | 12 | 39.3 | 1 | 36.3 | 5 | 40.1 | 2 |
| P. I. 92592 x Richland | 3915 | 42.2 | 22 | 36.8 | 10 | 35.6 | 9 | 38.2 | 14 |
| P. I. 92608 x Richland | 4015 | 42.7 | 18 | 36.7 | 11 | 34.3 | 21 | 37.9 | 19 |
| P. I. 92611 x Richland | 4115 | 38.2 | 25 | 36.3 | 13 | 34.6 | 19 | 36.4 | 23 |
| P. I. 92707 x Richland | 4215 | 43.3 | 16 | 35.0 | 16 | 36.3 | 5 | 38.2 | 14 |
| Richland x P. I. 92717 | 1543 | 43.7 | 14 | 33.0 | 23 | 35.6 | 9 | 37.5 | 20 |
| Lincoln | ......... | 52.8 | ......... | 41.8 | ......... | 39.9 | ......... | 44.8 | ......... |
| Richland | ......... | 39.7 | ......... | 33.3 | ......... | 35.7 | ......... | 36.2 | ......... |
| Mukden | ......... | 41.0 | ......... | 35.4 | ......... | 35.1 | ......... | 37.1 | ......... |

[1]The first two digits in each cross number represent the female parent and the last two the male parent; e.g. in cross 1115, Dunfield was parent 11 and Richland was parent 15.

TABLE 5. ANALYSIS OF VARIANCE OF YIELDS AND COEFFICIENTS OF VARIATION FOR BULK $F_2$, $F_3$ AND $F_4$ YIELD TESTS OF 25 SOYBEAN CROSSES AND THREE CHECK VARIETIES GROWN IN SUCCESSIVE YEARS.

| Source of variation | D. F. | Mean squares | | | |
|---|---|---|---|---|---|
| | | Bulk $F_2$ generation 1943 | Bulk $F_3$ generation 1944 | Bulk $F_4$ generation 1945 | Combined 1943 to 1945 |
| Replications | 5, 5, 5, 15 | 64.74 | 18.17 | 47.32 | 43.41 |
| Crosses and varieties* | 29 | 67.63** | 36.58** | 17.86** | 82.53** |
| Generations (years) | 2 | .......... | .......... | .......... | 4,334.90** |
| Crosses and varieties x generations | 58 | .......... | .......... | .......... | 19.77** |
| Experimental error | 145, 145, 145, 435 | 13.00 | 8.71 | 7.55 | 9.74 |
| Coefficient of variation | .................... | 8.1% | 8 2% | 7.7% | 8.1% |

*Of the varieties, Lincoln and Richland were entered twice and Mukden once in each test.
**Significant at the 1 percent level.

of years have shown similar differences in yield among the three varieties.

Differences in mean yield among varieties and bulk populations of the crosses were highly significant in each test and in the combined test, as shown by analyses of variance in table 5. The average yield of all entries varied considerably among years because of seasonal fluctuations. One of the more important features of the combined analysis from the standpoint of bulk yield testing was the highly significant interaction of crosses and varieties with generations. This indicated that the relative differences in yield among the crosses and varieties were not the same from generation to generation (year to year). Certain of the crosses, e.g. Mukden x Richland and L34R12 x Richland, were relatively high in yield in each test. P. I. 79885 x Richland and P. I. 89009-2 x Richland, on the other hand, were consistently low in yield. Other crosses, however, varied considerably in yield rank from year to year. The cross Manchuria 13-177 x Richland was first in yield rank in the bulk $F_2$ test, eighth in the bulk $F_3$ test and twenty-second in the bulk $F_4$ test. Conversely, P. I. 65346 x Richland was twenty-fourth in 1943, third in 1944 and first in 1945. Although the latter two crosses were the extremes for this type of comparison, several others performed in a similar manner. Results with this group of bulk crosses certainly would leave some doubt as to the feasibility of relying upon a bulk yield test of the $F_2$ generation alone for measuring differences in yield performance among bulk populations of soybean crosses.

Another important feature was apparent when these results were compared with those obtained in the $F_1$ generation for four of the crosses. In the $F_1$ generation Mukden x Richland seemed to be the poorest and P. I. 89009-2 x Richland one of the best in respect to yield. The situation was reversed, however, in bulk population tests where Mukden x Richland was the best and P. I. 89009-2 x Richland the poorest in yield in each generation. Several reasons for this reversal in performance may be postulated. One is that there possibly was an interaction between the two methods of planting, since the $F_1$ generation was space-planted and the segregating populations drilled. Another is the probable difference in experimental accuracy of the results. A third postulation is that the degree of dominance and the extent of segregation for yield genes were variable among the crosses. Very probably all of these factors influenced the performance of the crosses to some extent at the successive generations studied.

Differences in combining ability among various varieties and strains of soybeans have previously received little study in hybridization work. Consequently, parents for crosses have been selected primarily on the basis of their performance in test plots rather than on a combination of performance and known breeding prepotency. Yields of bulk populations of Lincoln x Richland and Mukden x Richland provided some interesting information on combining ability. Since Richland was a common parent to both crosses, yields of the bulk populations of these crosses might be used as an indication of the contributions of the Mukden and Lincoln parents to the crosses. Lincoln has consistently outyielded Mukden in varietal test plots at Ames, although the two varieties are similar in other important agronomic characteristics. It was expected, therefore, that the bulk populations of Lincoln x Richland would be higher yielding than those of Mukden x Richland. The results, however, were not in agreement with this expectation. Each of the bulk generations of Mukden x Richland outyielded those of Lincoln x Richland. Differences became smaller, however, with each successive generation. When compared with parental yields, Lincoln x Richland was lower than the mean of the two parents in each bulk test, while Mukden x Richland was above the yield of the higher yielding parent. These results indicated that the combining ability for yield of Mukden with Richland was better than that of Lincoln with Richland. Similar differences in combining ability probably existed among the other parents but could not be evaluated in this way because all parents were not included in the bulk tests.

## MATURITY

Time of maturity is another agronomic character of considerable importance in soybeans. Varieties that mature about the time of the first killing frost in the fall in any locality usually yield more on the average than those which mature either sooner or later. Consequently, it is an important factor in the evaluation of segregating populations.

Mean maturities of bulk $F_2$, $F_3$ and $F_4$ generations of the 25 crosses

TABLE 6. MEAN MATURITIES IN NUMBER OF DAYS AFTER AUGUST 31 OF BULK $F_2$, $F_3$ AND $F_4$ GENERATIONS OF 25 SOYBEAN CROSSES AND THREE CHECK VARIETIES GROWN IN SUCCESSIVE YEARS.

| Cross number or variety* | Bulk $F_2$ 1943 | Bulk $F_3$ 1944 | Bulk $F_4$ 1945 | Average 1943 to 1945 |
|---|---|---|---|---|
| 1115 | 30 | 29 | 40 | 33 |
| 1315 | 33 | 34 | 42 | 36 |
| 1415 | 23 | 27 | 36 | 29 |
| 1512 | 32 | 33 | 42 | 35 |
| 1516 | 31 | 30 | 40 | 34 |
| 1517 | 13 | 10 | 24 | 16 |
| 1518 | 26 | 26 | 37 | 29 |
| 1519 | 26 | 25 | 36 | 29 |
| 2715 | 36 | 35 | 44 | 38 |
| 2815 | 33 | 35 | 43 | 37 |
| 2915 | 32 | 35 | 42 | 36 |
| 3015 | 33 | 36 | 42 | 37 |
| 3115 | 29 | 26 | 37 | 31 |
| 3215 | 28 | 27 | 38 | 31 |
| 3315 | 28 | 26 | 39 | 31 |
| 1534 | 33 | 33 | 43 | 36 |
| 3515 | 27 | 26 | 37 | 30 |
| 3615 | 28 | 27 | 38 | 31 |
| 3715 | 32 | 36 | 44 | 37 |
| 3815 | 29 | 27 | 39 | 31 |
| 3915 | 29 | 27 | 37 | 31 |
| 4015 | 28 | 26 | 39 | 31 |
| 4115 | 28 | 27 | 38 | 31 |
| 4215 | 31 | 28 | 41 | 33 |
| 1543 | 33 | 32 | 41 | 35 |
| Lincoln | 30 | 27 | 37 | 31 |
| Richland | 20 | 18 | 30 | 23 |
| Mukden | 26 | 26 | 39 | 30 |

*Parentage of crosses appears in table 4.

and three varieties appear in table 6. The average maturity of all entries was about the same in 1943 and 1944 but, because of a cool, wet spring, approximately a week later in 1945. Differences between the bulk crosses in time of maturity were evident in each generation and remained fairly consistent from year to year. Although the method used to measure maturity was biased towards the later side, the maturities of the bulk populations were somewhat indicative of the relative proportions of early, medium and late types in each cross. As an example, bulk generations of cross 1517 were composed primarily of plants earlier than Richland, which was the later of the two parents.

The same crosses used to indicate differences in combining ability for yield among the parental varieties can be used for the same purpose with maturity. Bulk generations of cross 1415 were similar to the later parent in average maturity. Bulk populations of cross 3015, however, were definitely later than Lincoln, the later parent. If the parents had been included, cross 2715 probably would have been slightly earlier in average maturity than the later parent and crosses 3515 and 3715 somewhat later than the later parent in the same respect. These possibilities would have been in accord with the postulations based on maturity measurements made in the $F_1$ generations of these crosses. Maturity readings in early generations of bulk soybean crosses, therefore, may give some indication not only of the maturity composition of the populations of each cross but also of the genotype of the parents.

### HEIGHT

Certain varieties of soybeans, when grown in Iowa, are too short to harvest satisfactorily with a combine. This is one of the disadvantages of Richland when grown on lighter soils. It is desirable, therefore, to develop varieties tall enough so that all pods on the lower parts of the stems can be harvested. As shown in table 7, all bulk crosses were taller than the Richland parent in average plant height. Almost half of them were about as tall as Lincoln and Mukden, varieties with a satisfactory height for combining. A few, however, were only an inch or two taller than Richland in average height.

Results obtained with four of these crosses in the space-planted $F_1$ generation showed that cross 3715 was the only one which exceeded both parents in average plant height. The other three were between the two parents in the same respect. Average heights of

TABLE 7. MEAN HEIGHTS IN INCHES OF BULK $F_2$, $F_3$ AND $F_4$ GENERATIONS OF 25 SOYBEAN CROSSES AND THREE CHECK VARIETIES GROWN IN SUCCESSIVE YEARS.

| Cross number or variety* | Bulk $F_2$ 1943 | Bulk $F_3$ 1944 | Bulk $F_4$ 1945 | Average 1943 to 1945 |
|---|---|---|---|---|
| 1115 | 46 | 37 | 39 | 40 |
| 1315 | 48 | 38 | 38 | 41 |
| 1415 | 43 | 37 | 39 | 40 |
| 1512 | 46 | 37 | 41 | 41 |
| 1516 | 46 | 36 | 39 | 40 |
| 1517 | 38 | 27 | 38 | 34 |
| 1518 | 41 | 33 | 38 | 37 |
| 1519 | 41 | 34 | 38 | 38 |
| 2715 | 49 | 37 | 36 | 41 |
| 2815 | 44 | 37 | 39 | 40 |
| 2915 | 44 | 37 | 39 | 40 |
| 3015 | 47 | 38 | 40 | 42 |
| 3115 | 44 | 34 | 36 | 38 |
| 3215 | 39 | 33 | 34 | 35 |
| 3315 | 40 | 32 | 36 | 36 |
| 1534 | 38 | 33 | 37 | 36 |
| 3515 | 38 | 30 | 34 | 34 |
| 3615 | 41 | 34 | 36 | 37 |
| 3715 | 43 | 36 | 37 | 39 |
| 3815 | 43 | 35 | 37 | 39 |
| 3915 | 43 | 34 | 36 | 38 |
| 4015 | 42 | 34 | 35 | 37 |
| 4115 | 40 | 34 | 39 | 37 |
| 4215 | 44 | 35 | 37 | 39 |
| 1543 | 45 | 36 | 39 | 40 |
| Lincoln | 47 | 37 | 40 | 41 |
| Richland | 36 | 28 | 35 | 33 |
| Mukden | 47 | 38 | 41 | 42 |

*Parentage of crosses appears in table 4.

TABLE 8. MEAN LODGING SCORES OF BULK $F_2$, $F_3$ AND $F_4$ GENERATIONS OF 25 SOYBEAN CROSSES AND THREE CHECK VARIETIES GROWN IN SUCCESSIVE YEARS.

| Cross number or variety* | Bulk $F_2$ 1943 | Bulk $F_3$ 1944 | Bulk $F_4$ 1945 | Average 1943 to 1945 |
|---|---|---|---|---|
| 1115 | 3.0 | 1.2 | 2.7 | 2.3 |
| 1315 | 3.0 | 1.8 | 2.8 | 2.6 |
| 1415 | 2.8 | 1.0 | 2.2 | 2.0 |
| 1512 | 3.0 | 1.2 | 2.7 | 2.3 |
| 1516 | 3.0 | 1.5 | 2.8 | 2.4 |
| 1517 | 2.0 | 1.0 | 1.0 | 1.3 |
| 1518 | 3.0 | 1.5 | 2.2 | 2.2 |
| 1519 | 3.0 | 1.5 | 2.2 | 2.2 |
| 2715 | 3.8 | 1.8 | 3.0 | 2.9 |
| 2815 | 3.0 | 1.5 | 2.8 | 2.4 |
| 2915 | 3.0 | 1.5 | 2.8 | 2.4 |
| 3015 | 3.0 | 1.3 | 2.5 | 2.3 |
| 3115 | 3.0 | 1.7 | 2.5 | 2.4 |
| 3215 | 3.2 | 1.3 | 2.8 | 2.4 |
| 3315 | 3.2 | 1.2 | 2.5 | 2.3 |
| 1534 | 3.3 | 1.7 | 3.0 | 2.7 |
| 3515 | 3.2 | 1.0 | 2.7 | 2.3 |
| 3615 | 3.0 | 1.5 | 2.3 | 2.3 |
| 3715 | 3.0 | 1.3 | 3.2 | 2.5 |
| 3815 | 3.3 | 1.5 | 2.8 | 2.6 |
| 3915 | 3.0 | 1.0 | 2.2 | 2.1 |
| 4015 | 3.3 | 1.3 | 2.7 | 2.4 |
| 4115 | 3.5 | 1.3 | 2.5 | 2.4 |
| 4215 | 3.0 | 1.3 | 2.7 | 2.3 |
| 1543 | 3.0 | 1.3 | 2.5 | 2.3 |
| Lincoln | 3.0 | 1.9 | 2.8 | 2.6 |
| Richland | 2.7 | 1.0 | 1.3 | 1.7 |
| Mukden | 2.8 | 1.2 | 3.2 | 2.4 |

*Parentage of crosses appears in table 4.

the same crosses in the bulk tests agreed quite well with the $F_1$ expectations. Cross 1415 was between the two parents in height in each bulk test. Cross 3715, on the other hand, was definitely taller than Richland, the taller of the two parents, in each generation from bulk $F_2$ to bulk $F_4$. In this case height differences among the crosses, as measured in $F_1$, were related to average performance of subsequent bulk generations.

## LODGING SCORE

Lodging, like plant height, is an important factor in combine harvesting of the soybean crop. Difficulties are measurably increased when lodging-susceptible varieties are grown on the fertile soil types. It was primarily because of its high degree of lodging resistance that Richland was selected as the common parent for these crosses. As indicated by the lodging scores in table 8, bulk populations of the crosses differed in their ability to stand up. Although only one of the crosses lodged less than Richland, most of them stood up as well as Mukden, whose lodging resistance generally has been better than most other parental varieties of the 25 crosses in test plots at Ames.

In bulk tests the cross Manchuria 13-177 x Richland (cross 2715)

TABLE 9. CORRELATION COEFFICIENTS FOR MEAN YIELDS, MATURITIES, HEIGHTS AND LODGING SCORES AMONG BULK $F_2$, $F_3$ AND $F_4$ GENERATIONS OF 25 SOYBEAN CROSSES GROWN IN SUCCESSIVE YEARS.

| Bulk generations and years | D. F. | Yield | Maturity | Height | Lodging score |
|---|---|---|---|---|---|
| $F_2$ 1943 and $F_3$ 1944 | 23 | .20 | .93** | .84** | .43* |
| $F_2$ 1943 and $F_4$ 1945 | 23 | .15 | .96** | .46* | .73** |
| $F_3$ 1944 and $F_4$ 1945 | 23 | .29 | .96** | .51** | .45* |

*P less than 0.05.
**P less than 0.01.

was poorest in lodging resistance, while Mukden x Richland (cross 1415) was one of the best. Bulk populations of crosses 3515 and 3715 were intermediate among the crosses for lodging score. Most bulk crosses contained a sufficient number of plants with good lodging resistance for effective selection of this character.

## CORRELATIONS

Correlations between bulk generations of the crosses were calculated for each of the four agronomic characters studied to obtain a measure of consistency in performance in consecutive years. These correlations are shown in table 9. None for yield approached significance. Those for the other characters, however, all were statistically significant. Results for any one generation or year apparently were a poor indication of differences in yield performance among the bulk populations of the crosses. Differences in maturity, height and lodging, on the other hand, were evaluated with reasonable accuracy in any one of the bulk generations.

## 1945 BULK $F_3$ TEST

An additional bulk yield test of the $F_3$ generations of the four crosses selected for study on a pedigree basis was grown in 1945. The same varieties as used in previous bulk tests were included as checks.

TABLE 10. MEAN YIELDS, MATURITIES IN NUMBER OF DAYS AFTER AUGUST 31, HEIGHTS AND LODGING SCORES OF BULK $F_3$ GENERATIONS OF FOUR SOYBEAN CROSSES GROWN IN 1945 WITH THREE CHECK VARIETIES.

| Cross number or variety* | Yield (Bushels per acre) | Maturity | Height in inches | Lodging score |
|---|---|---|---|---|
| 1415 | 34.4 | 37 | 38 | 2.7 |
| 2715 | 36.9 | 44 | 36 | 3.2 |
| 3515 | 34.8 | 37 | 32 | 2.8 |
| 3715 | 31.0 | 43 | 37 | 3.2 |
| Lincoln | 38.8 | 38 | 39 | 2.5 |
| Richland | 36.3 | 30 | 36 | 1.2 |
| Mukden | 34.8 | 38 | 40 | 2.8 |

*Parentage of crosses appears in table 4.

TABLE 11. ANALYSIS OF VARIANCE OF YIELDS AND THE COEFFICIENT OF VARIATION FOR BULK $F_3$ TEST OF FOUR SOYBEAN CROSSES AND THREE CHECK VARIETIES GROWN IN 1945.

| Source of variation | D. F. | Mean square |
|---|---|---|
| Replications | 5 | 17.52 |
| Crosses and varieties | 6 | 35.45* |
| Experimental error | 30 | 3.89 |
| Coefficient of variation | | 5.6% |

*Significant at the 1 percent level.

Mean agronomic results obtained in this test are presented in table 10. The analysis of variance of yields and the coefficient of variation appear in table 11. As the mean yields of the crosses varied more than the mean yields of the varieties, little would have been gained by partitioning the mean squares for crosses and varieties and experimental error into their component parts.

In this test the relative differences among the crosses and varieties in maturity, height and lodging score were very similar to those found in the other bulk population trials. Yields of the three check varieties also were about the same as in the bulk $F_4$ test conducted that year. Differences in yield among the bulk $F_3$ populations of the crosses, however, were not the same. Cross 2715 was the highest of the four crosses in yield in this test. Crosses 1415 and 3515 were intermediate in yield, and cross 3715 was the lowest in yield. These results further substantiated the inconsistencies in yield performance of the bulk populations at successive generations and in different years.

## $F_2$ GENERATION SPACED PLANT STUDY

Among plant breeders the pedigree method of handling segregating populations of crosses in self-pollinated crops is used more commonly than the bulk method. Selection of desirable plants in $F_2$ generally is based on visual observations of the characteristics of each plant. Characters which are simply inherited usually can be easily selected. Characters inherited in a complex manner, on the other hand, are difficult to select for, since the environment may mask the true expression of the genotype of a plant. Most plant breeders select only the most vigorous, high yielding $F_2$ plants which appear satisfactory for time of maturity, plant height and other desired characters within each cross. This practice, in light of the probable effects of environment on plant phenotypes, raises a question as to its value in a breeding program. In other words, are observed differences for such complex characters as yield, maturity and height among spaced $F_2$ plants of a cross primarily of an environmental nature or of a genetic nature due to segregation? The greater the effects of the

TABLE 12. FREQUENCY DISTRIBUTIONS FOR SEED YIELD PER PLANT OF 100 CONSECUTIVE COMPETITIVE PLANTS IN $F_2$ GENERATIONS OF EACH OF FOUR SOYBEAN CROSSES AND IN EACH OF THREE VARIETIES WITH THEIR MEANS, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION.

| Yield in grams per plant (Class center) | Mukden x Richland (Cross 1415) | Manchuria 13-177 x Richland (Cross 2715) | P. I. 79885 x Richland (Cross 3515) | P. I. 89009-2 x Richland (Cross 3715) | Richland | Mukden | Lincoln |
|---|---|---|---|---|---|---|---|
| 5 | ...... | ...... | 1 | ...... | ...... | ...... | ...... |
| 10 | ...... | 2 | 1 | 2 | ...... | 2 | ...... |
| 15 | 1 | 2 | 4 | 12 | ...... | 6 | ...... |
| 20 | 5 | 1 | 10 | 7 | 1 | 11 | 5 |
| 25 | 6 | 7 | 14 | 6 | 4 | 17 | 5 |
| 30 | 11 | 2 | 14 | 13 | 8 | 14 | 11 |
| 35 | 8 | 12 | 18 | 6 | 14 | 17 | 24 |
| 40 | 10 | 7 | 12 | 12 | 20 | 13 | 19 |
| 45 | 14 | 12 | 12 | 7 | 20 | 15 | 11 |
| 50 | 16 | 8 | 4 | 6 | 14 | 3 | 11 |
| 55 | 6 | 7 | 3 | 4 | 9 | 2 | 6 |
| 60 | 10 | 14 | 4 | 11 | 7 | ...... | 3 |
| 65 | 7 | 4 | 1 | 1 | 1 | ...... | 2 |
| 70 | 3 | 10 | 1 | 5 | 2 | ...... | 2 |
| 75 | 2 | 3 | 1 | 2 | ...... | ...... | ...... |
| 80 | 1 | 3 | ...... | 1 | ...... | ...... | ...... |
| 85 | ...... | 2 | ...... | 2 | ...... | ...... | 1 |
| 90 | ...... | 2 | ...... | 3 | ...... | ...... | ...... |
| 95 | ...... | 2 | ...... | ...... | ...... | ...... | ...... |
| Mean | 45.26 | 51.60 | 35.15 | 41.49 | 43.64 | 32.35 | 40.48 |
| Standard deviation | 14.50 | 19.06 | 13.06 | 20.49 | 10.19 | 10.27 | 11.81 |
| Coefficient of variation | 32 0 % | 36.9 % | 37.1 % | 49.4 % | 23.3 % | 31.7 % | 29.2 % |

TABLE 13. FREQUENCY DISTRIBUTIONS FOR MATURITY IN NUMBER OF DAYS AFTER AUGUST 31 OF 100 CONSECUTIVE COMPETITIVE PLANTS IN $F_2$ GENERATIONS OF EACH OF FOUR SOYBEAN CROSSES AND IN EACH OF THREE VARIETIES WITH THEIR MEANS, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION.

| Days after August 31 (Class center) | Mukden x Richland (Cross 1415) | Manchuria 13-177 x Richland (Cross 2715) | P. I. 79885 x Richland (Cross 3515) | P. I. 89009-2 x Richland (Cross 3715) | Richland | Mukden | Lincoln |
|---|---|---|---|---|---|---|---|
| 0 | | | 1 | | | | |
| 5 | | 1 | 5 | 4 | | | |
| 10 | | 9 | 15 | 4 | | | |
| 15 | 13 | 15 | 37 | 13 | 11 | 7 | |
| 20 | 22 | 10 | 15 | 2 | 49 | 32 | 13 |
| 25 | 37 | 15 | 16 | 15 | 38 | 42 | 58 |
| 30 | 24 | 9 | 7 | 39 | 2 | 17 | 29 |
| 35 | 2 | 13 | 3 | 11 | | 2 | |
| 40 | 2 | 17 | 1 | 9 | | | |
| 45 | | 8 | | 3 | | | |
| 50 | | 2 | | | | | |
| 55 | | 1 | | | | | |
| Mean | 24 | 29 | 18 | 27 | 22 | 24 | 26 |
| Standard deviation | 5.36 | 11.60 | 7.37 | 9.26 | 3.16 | 4.00 | 2.75 |
| Coefficient of variation | 21.9 % | 40.7 % | 40.7 % | 34.1 % | 14.6 % | 16.8 % | 10.5 % |

environment, the less will be the breeding value of visual selection for these characters. The pedigree studies reported herein were conducted in an attempt to gain further information on this problem as it relates to selection in segregating populations of soybean crosses.

Measurements for seed yield, maturity and height were made individually on 100 consecutive competitive spaced plants in each of three varieties and in the $F_2$ generation of each of four crosses. Frequency distributions of seed yield per plant for these crosses and varieties are found in table 12. The mean, standard deviation and coefficient of variation for each distribution also are included. The means were not comparable, since there were no replications, but the distributions and their standard deviations provided interesting comparisons among the crosses and varieties. Although the range in seed yield was greater for each of the crosses than for any of the three varieties, the differences were not nearly as large as was expected. These relatively small differences were substantiated by the standard deviations, which were not much larger for two of the crosses than for the varieties. The standard deviations for the other two crosses, however, were about twice as large as those of the varieties. These results indicated that a major portion of the variability in seed yield among $F_2$ plants of each cross was due to environmental rather than genetic causes. Selection for differences in yielding ability among these plants, therefore, probably would not have been too valuable from a genetic standpoint.

Date of maturity in soybeans generally is not affected as much by the environment as is yield. As shown by the frequency distributions in table 13, range in maturity of $F_2$ plants in each cross was greater than that of the plants in any variety. Differences in maturity among $F_2$ plants of each cross apparently were affected more by genetic segregation than differences in yield, as indicated by the relative sizes of the standard deviations of the crosses in comparison with those for varieties. Consequently, selection for maturity differences among $F_2$ plants of each cross might have been of more value genetically than selection for differences in yielding ability.

Frequency distributions for plant heights in inches of each $F_2$ cross and variety appear in table 14. In general, there was somewhat less variability for plant height among the crosses than there was for maturity. Coefficients of variation of height distributions for two of the crosses were not greatly different than those of the varieties, but for the other two crosses, they were more than twice as large. In the latter two crosses, namely, crosses 3515 and 3715, genetic segregation probably accounted for a greater proportion of the total variation for height than it did for yield. The range in plant height among $F_2$ plants of cross 3715 indicated that a certain amount of transgressive segregation occurred for this character, since Richland was the taller of the two parents. In fact, the $F_2$ plant results with this cross agreed very closely with the suppositions made

TABLE 14. FREQUENCY DISTRIBUTIONS FOR PLANT HEIGHT IN INCHES OF 100 CONSECUTIVE COMPETITIVE PLANTS IN $F_2$ GENERATIONS OF EACH OF FOUR SOYBEAN CROSSES AND IN EACH OF THREE VARIETIES WITH THEIR MEANS, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION.

| Plant height in inches (Class center) | Mukden x Richland (Cross 1415) | Manchuria 13-177 x Richland (Cross 2715) | P. I. 79885 x Richland (Cross 3515) | P. I. 89009-2 x Richland (Cross 3715) | Richland | Mukden | Lincoln |
|---|---|---|---|---|---|---|---|
| 5 | | | | 1 | | | |
| 10 | | | 5 | 4 | | | |
| 15 | | | 27 | 14 | | | |
| 20 | 1 | | 31 | 9 | 5 | | |
| 25 | 13 | 4 | 18 | 10 | 71 | 12 | 4 |
| 30 | 24 | 22 | 16 | 26 | 24 | 23 | 23 |
| 35 | 38 | 45 | 3 | 23 | | 54 | 56 |
| 40 | 20 | 29 | | 12 | | 11 | 15 |
| 45 | 3 | | | 1 | | | 2 |
| 50 | 1 | | | | | | |
| Mean | 34.08 | 34.98 | 20.96 | 28.13 | 25.90 | 33.07 | 34.86 |
| Standard deviation | 5.15 | 4.00 | 5.93 | 9.02 | 2.36 | 4.07 | 3.41 |
| Coefficient of variation | 15.1 % | 11.4 % | 28.3 % | 32.0 % | 9.1 % | 12.3 % | 9.8 % |

about its height potentialities on the basis of the spaced $F_1$ plant and bulk population tests. An unexpected result in the $F_2$ plant study was the relatively narrow range for plant height in cross 2715. As the two parents of this cross differed widely in plant height and the same $F_2$ plants were among the most variable of the four crosses for yield and maturity, a greater range in plant height was expected.

The 100 spaced $F_2$ plants per cross that were measured for their agronomic characteristics constituted a reasonably random sample of the $F_2$ population of plants in each of the crosses. As the crosses were not replicated, the plants were grown and harvested under conditions similar to those usually encountered in making plant selections in segregating populations. The common practice of selecting only the better yielding plants in segregating populations of crosses did not seem justified on the basis of results secured in this study. If these samples of $F_2$ plants truly gave an indication of the extent of variability for seed yield among all plants of the $F_2$ populations, random selection of plants probably would have been about as successful in the attainment of high yielding genotypes in these populations as the selection of high yielding plants. Replicated progeny tests of most of these plants were grown in the $F_3$ generation the next year to obtain additional information on breeding behavior of the $F_2$ generation. $F_3$ generation results are presented and discussed in the succeeding section.

## $F_3$ LINE TEST

In the previous section it was shown that the environment appeared to have a pronounced effect on phenotypic differences among $F_2$ plants of four soybean crosses included in this investigation. If the usual pedigree method of breeding had been continued, seed from the most desirable appearing $F_2$ plants would have been planted in progeny rows the succeeding year. Here again the environment probably would have influenced the expression of agronomic differences among the lines.

Most of the $F_2$ plants in each cross produced sufficient seed for planting replicated progeny tests. In all, progenies of 77 of the $F_2$ plants per cross were planted in 1945 to study their breeding behavior in $F_3$. This procedure made possible a more accurate appraisal of agronomic differences among the $F_3$ lines than the usual pedigree method. It also made possible a comparison of the characteristics of individual $F_2$ plants and the means of their replicated progenies in the $F_3$ generation.

### SEED YIELD

As shown by the analyses of variance of yields of the 77 $F_3$ lines, parents and bulk $F_2$ and $F_3$ generations in each of the four crosses in table 15, the mean yield differences among the entries were highly significant in three of the four crosses. In the fourth cross the

TABLE 15. ANALYSES OF VARIANCE OF YIELDS OF 77 $F_3$ LINES, PARENTS AND BULK $F_2$ AND $F_3$ GENERATIONS OF EACH OF FOUR SOYBEAN CROSSES.

| Source of variation | D. F. | Mean squares | | | |
|---|---|---|---|---|---|
| | | Mukden x Richland (Cross 1415) | Manchuria 13-177 x Richland (Cross 2715) | P. I. 79885 x Richland (Cross 3515) | P. I. 89009-2 x Richland (Cross 3715) |
| Replications | 2 | 946.26 | 82 72 | 356.23 | 1,504.08 |
| Blocks (eliminating lines) | 24 | 25.06 | 30 73 | 19.40 | 27.97 |
| Lines (ignoring blocks) | 80 | 23.26* | 61.12* | 35.13* | 22.87 |
| Error (intrablock) | 134, 134, 136, 136 | 10.17 | 18.53 | 13.01 | 14.92 |
| Error (randomized complete block) | 158, 158, 160, 160 | 12.43 | 20.39 | 13.97 | 16.88 |
| General mean in bushels per acre | | 44.6 | 44.2 | 47.7 | 40.2 |
| Precision | | 112.2% | 103.9% | 102.3% | 105.8% |
| Coefficient of variation | | 7.5% | 10.0% | 7.7% | 9.9% |
| Average standard error of a difference (bushels per acre) | | 2.72 | 3.62 | 3.02 | 3.26 |

*Significant at the 1 percent level.

differences approached significance. Frequency distributions of mean yields of $F_3$ lines in each of the crosses, however, showed that only a few of the lines were significantly higher or lower in yield than Richland, the common parent. These distributions are recorded in table 16. Since Richland generally had yielded less than the other parents of these crosses in most replicated tests at Ames, the results indicated that opportunities for selecting lines superior in yield to the parents did not appear very promising.

Yield results did not agree very well with those obtained in bulk population trials of the same crosses. Bulk $F_3$ generations of crosses 1415 and 2715 were slightly below Richland in yield in this test, while those of crosses 3515 and 3715 were slightly above. In the bulk population studies, on the other hand, crosses 1415 and 2715 generally were well above Richland in yield, while crosses 3515 and 3715 yielded about the same as Richland. Frequency distributions of yields of $F_3$ lines, furthermore, showed no superiority in yield of cross 2715 over that of cross 3515. Cross 3715, which was the lowest yielding of the four crosses in bulk tests, actually appeared to have a more favorable yield distribution of $F_3$ lines than either of the latter two crosses. The relative yield performance of cross 1415, however, was very similar in the bulk and pedigree tests when the same type of comparison was made. It also was of interest to note that cross 3715, which had the greatest standard deviation of all crosses for seed yield in the $F_2$ spaced-plant study (see table 12), had the lowest and only non-significant mean square for lines in the $F_3$ test.

Each replication of the four crosses in this test was randomized first on a whole cross basis so that mean yields of the crosses could be compared. These general means are found in table 15. The chance placement of all replications of cross 3515 on the more fertile parts of the experimental area, as shown by the higher yield of Richland in this group, resulted in this cross having the highest mean

TABLE 16. FREQUENCY DISTRIBUTIONS OF MEAN YIELDS OF 77 $F_3$ LINES AND BULK $F_3$ GENERATIONS IN EACH OF FOUR SOYBEAN CROSSES, AS COMPARED TO THE YIELD OF RICHLAND.

| Cross | Class centers of minus 3.5 to plus 3.5 times the average standard error of a difference | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | −4 to −3 | −3 to −2 | −2 to −1 | −1 to 0 | 0 to +1 | +1 to +2 | +2 to +3 | +3 to +4 |
| Mukden x Richland (Cross 1415) | ...... | ...... | 8 | 22 | 29 | 14 | 3 | 1 |
| Bulk $F_3$ generation | ...... | ...... | ...... | 1 | ...... | ...... | ...... | ...... |
| Manchuria 13-177 x Richland (Cross 2715) | 1 | 4 | 7 | 31 | 18 | 14 | 2 | ...... |
| Bulk $F_3$ generation | ...... | ...... | ...... | 1 | ...... | ...... | ...... | ...... |
| P. I. 79885 x Richland (Cross 3515) | 1 | 5 | 12 | 28 | 20 | 10 | 1 | ...... |
| Bulk $F_3$ generation | ...... | ...... | ...... | ...... | 1 | ...... | ...... | ...... |
| P. I. 89009-2 x Richland (Cross 3715) | ...... | ...... | 3 | 23 | 32 | 18 | 1 | ...... |
| Bulk $F_3$ generation | ...... | ...... | ...... | ...... | 1 | ...... | ...... | ...... |

yield of the four crosses. As the replications of the other crosses were affected favorably in some instances and unfavorably in others by their placement in the field, these general means among the crosses could not be validly compared.

## MATURITY

Maturity differences among $F_3$ lines were much more striking than yield differences. Frequency distributions of the mean maturities, presented in table 17, showed that all four of the crosses contained $F_3$ lines earlier and later than either parent. The extent of transgressive segregation for factors conditioning maturity was greatest for cross 3515. The range in maturity among $F_3$ lines was smallest for cross 1415. Consequently, it had the smallest mean square for lines of the four crosses, as shown by the analyses of variance of maturities in table 18. The $F_3$ lines in cross 2715, on the other hand, had the greatest range in maturity and the largest mean square for lines. Crosses 3515 and 3715 were intermediate for maturity range and line mean square. These results conformed with maturity measurements made on parental $F_2$ plants of these lines (see table 13), where cross 1415 had the lowest and cross 2715 the highest standard deviation for maturity among the 100 $F_2$ plants in each cross. Similarly, crosses 3515 and 3715 each had an intermediate standard deviation for maturity among their $F_2$ plants.

The low coefficients of variation and average standard errors of a difference (table 18) indicated that maturity differences among the $F_3$ lines in each cross were evaluated with considerable accuracy. Opportunities for selecting $F_3$ lines from these crosses that were significantly different in maturity, therefore, appeared very good.

TABLE 17. FREQUENCY DISTRIBUTIONS OF MEAN MATURITIES IN NUMBER OF DAYS AFTER AUGUST 31 OF 77 $F_3$ LINES, PARENTS AND BULK $F_3$ GENERATIONS IN EACH OF FOUR SOYBEAN CROSSES.

| Cross or parent | Days after August 31 (class centers) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 23 | 26 | 29 | 32 | 35 | 38 | 41 | 44 | 47 |
| Mukden x Richland (Cross 1415) | .... | 1 | 5 | 11 | 37 | 16 | 5 | 2 | .... | .... |
| Richland | .... | .... | .... | 1 | .... | .... | .... | .... | .... | .... |
| Mukden | .... | .... | .... | .... | .... | 1 | .... | .... | .... | .... |
| Bulk $F_3$ generation | .... | .... | .... | .... | .... | 1 | .... | .... | .... | .... |
| Manchuria 13-177 x Richland (Cross 2715) | 2 | 2 | 6 | 3 | 12 | 6 | 5 | 29 | 10 | 2 |
| Richland | .... | .... | .... | 1 | .... | .... | .... | .... | .... | .... |
| Manchuria 13-177 | .... | .... | .... | .... | .... | .... | .... | 1 | .... | .... |
| Bulk $F_3$ generation | .... | .... | .... | .... | .... | .... | .... | 1 | .... | .... |
| P. I. 79885 x Richland (Cross 3515) | 1 | 5 | 7 | 16 | 21 | 9 | 13 | 5 | .... | .... |
| Richland | .... | .... | .... | 1 | .... | .... | .... | .... | .... | .... |
| P. I. 79885 | .... | .... | .... | .... | 1 | .... | .... | .... | .... | .... |
| Bulk $F_3$ generation | .... | .... | .... | .... | .... | 1 | .... | .... | .... | .... |
| P. I. 89009-2 x Richland (Cross 3715) | .... | 1 | 5 | 1 | 3 | 4 | 14 | 44 | 5 | .... |
| Richland | .... | .... | .... | 1 | .... | .... | .... | .... | .... | .... |
| P. I. 89009-2 | .... | .... | .... | .... | .... | .... | .... | 1 | .... | .... |
| Bulk $F_3$ generation | .... | .... | .... | .... | .... | .... | .... | 1 | .... | .... |

TABLE 18. ANALYSES OF VARIANCE OF MATURITIES OF 77 $F_3$ LINES, PARENTS AND BULK $F_2$ AND $F_3$ GENERATIONS IN EACH OF FOUR SOYBEAN CROSSES.

| Source of variation | D. F. | Mean squares | | | |
|---|---|---|---|---|---|
| | | Mukden x Richland (Cross 1415) | Manchuria 13-177 x Richland (Cross 2715) | P. I. 79885 x Richland (Cross 3515) | P. I. 89009-2 x Richland (Cross 3715) |
| Replications | 2 | 503.72 | 59.12 | 40 77 | 207.69 |
| Blocks (eliminating lines) | 24 | 3.14 | 8.48 | 4.48 | 7.01 |
| Lines (ignoring blocks) | 80 | 31.22* | 129.45* | 69.66* | 60.89* |
| Error (intrablock) | 136 | 1.98 | 1.64 | 1.91 | 2.65 |
| Error (randomized complete block) | 160 | 2.16 | 2.67 | 2.29 | 3.30 |
| General mean maturity | | 32 | 37 | 32 | 39 |
| Precision | | 103.3% | 145.1% | 110 6% | 113.8% |
| Coefficient of variation | | 4.5% | 3.7% | 4.5% | 4.4% |
| Average standard error of a difference (days) | | 1.2 | 1.1 | 1.2 | 1.4 |

*Significant at the 1 percent level.

The results obtained in this study of $F_3$ lines also provided information on breeding behavior for maturity of the early segregating generations. Average maturity for each of the crosses, given in table 18, indicated that crosses 2715 and 3715 contained greater numbers of later maturing $F_3$ lines than the other two crosses. Frequency distributions of maturities of the $F_3$ lines substantiated this indication. The same relative differences in maturity among these crosses were obtained in the $F_1$ generation, the bulk population tests and the space-planted $F_2$ generation. Breeding behavior for maturity on a cross basis, therefore, seemed relatively consistent during the early generations following hybridization.

### HEIGHT

Plant height was the third agronomic character measured in this test. Frequency distributions of mean heights in inches of the $F_3$ lines, parents and bulk $F_3$ generations in each of the four crosses appear in table 19. As shown, the total range in height among $F_3$ lines was about the same for each cross. Cross 3515, however, had the greatest number of short lines and cross 1415 the greatest number of tall lines. Crosses 2715 and 3715 were intermediate in this respect. The bulk $F_3$ generation was intermediate in height to the two parents in three of the four crosses. In the fourth cross, cross 3715, it was significantly taller than Richland, the taller of the two parents. These results agreed quite well with postulations made about plant height differences among these crosses based on the $F_1$ generation and bulk population tests. $F_3$ lines in cross 2715, however, averaged somewhat shorter than expected on the basis of the previous data.

Analyses of variance of heights of the $F_3$ lines, parents and bulk generations in each of the four crosses (table 20) showed that the mean differences in height among the $F_3$ lines were highly significant in each cross. Although F values for the line mean squares of height were smaller than the comparable ones of maturity, they were considerably larger than the comparable ones of yield. Coefficients of variation and average standard errors of a difference of the heights indicated that height differences among the $F_3$ lines were evaluated quite accurately. Effectiveness of selection between $F_3$ lines for height, therefore, probably would have been about as good as for maturity.

### LODGING SCORE

Improved lodging resistance was one of the primary reasons for making this group of soybean crosses. In the segregating populations it was hoped that lines with lodging scores about as low as Richland could be found. Frequency distributions of mean lodging scores of $F_3$ lines, parents and bulk $F_3$ generations in each of the four crosses,

TABLE 19. FREQUENCY DISTRIBUTIONS OF MEAN HEIGHTS IN INCHES OF 77 $F_3$ LINES, PARENTS AND BULK $F_3$ GENERATIONS IN EACH OF FOUR SOYBEAN CROSSES.

| Cross or parent | Height in inches | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 |
| Mukden x Richland (Cross 1415) | | | | | | 1 | 3 | 4 | 4 | 5 | 5 | 11 | 10 | 10 | 12 | 7 | 2 | 1 | 2 |
| Richland | | | | | | | | | | 1 | | | | | | | | | |
| Mukden | | | | | | | | | | | | | | 1 | | | | | |
| Bulk $F_3$ generation | | | | | | | | | | | | 1 | | | | | | | |
| Manchuria 13-177 x Richland (Cross 2715) | | | 1 | | 2 | 1 | 2 | 4 | 7 | 13 | 19 | 10 | 12 | 5 | 1 | | | | |
| Richland | | | | | | | | | | 1 | | | | | | | | | |
| Manchuria 13-177 | | | | | | | | | | | 1 | | | | | | | | |
| Bulk $F_3$ generation | | | | | | | | | | 1 | | | | | | | | | |
| P. I. 79885 x Richland (Cross 3515) | 2 | 7 | 9 | 6 | 11 | 11 | 12 | 9 | 4 | 2 | 2 | 1 | 1 | | | | | | |
| Richland | | | | | | | | | 1 | | | | | | | | | | |
| P. I. 79885 | 1 | | | | | | | | | | | | | | | | | | |
| Bulk $F_3$ generation | | | | | | | 1 | | | | | | | | | | | | |
| P. I. 89009-2 x Richland (Cross 3715) | | | 3 | 1 | 4 | | 6 | 2 | 3 | 5 | 12 | 10 | 9 | 15 | 5 | 2 | | | |
| Richland | | | | | | | | 1 | | | | | | | | | | | |
| P. I. 89009-2 | | | | | 1 | | | | | | | | | | | | | | |
| Bulk $F_3$ generation | | | | | | | | | | | | 1 | | | | | | | |

TABLE 20. ANALYSES OF VARIANCE OF HEIGHTS IN INCHES OF 77 $F_3$ LINES, PARENTS AND BULK $F_2$ AND $F_3$ GENERATIONS IN EACH OF FOUR SOYBEAN CROSSES.

| Source of variation | D. F. | Mean squares | | | |
|---|---|---|---|---|---|
| | | Mukden x Richland (Cross 1415) | Manchuria 13-177 x Richland (Cross 2715) | P. I. 79885 x Richland (Cross 3515) | P. I. 89009-2 x Richland (Cross 3715) |
| Replications | 2 | 420.16 | 138.53 | 59.41 | 78.73 |
| Blocks (eliminating lines) | 24 | 8.97 | 3.18 | 4.23 | 4.15 |
| Lines (ignoring blocks) | 80 | 26.74* | 14.40* | 20.47* | 33.27* |
| Error (intrablock) | 136 | 3.32 | 2.24 | 2.63 | 3.27 |
| Error (randomized complete block) | 160 | 4.17 | 2.38 | 2.87 | 3.40 |
| General mean height in inches | | 37.8 | 35.7 | 30 8 | 36.0 |
| Precision | | 114.9% | 101.7% | 103.2% | 100.9% |
| Coefficient of variation | | 5.1% | 4.3% | 5.4% | 5.1% |
| Average standard error of a difference (inches) | | 1.6 | 1.3 | 1.4 | 1.5 |

*Significant at the 1 percent level.

TABLE 21. FREQUENCY DISTRIBUTIONS OF MEAN LODGING SCORES OF 77 $F_3$ LINES, PARENTS AND BULK $F_3$ GENERATIONS IN EACH OF FOUR SOYBEAN CROSSES.

| Cross or parent | Lodging scores (class centers) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.1 | 1.4 | 1.7 | 2.0 | 2.3 | 2.6 | 2.9 | 3.2 | 3.5 | 3.8 | 4.1 |
| Mukden x Richland (Cross 1415) | 3 | 3 | 11 | 16 | 16 | 15 | 6 | 4 | 3 | .... | .... |
| Richland | .... | .... | .... | 1 | .... | .... | .... | .... | .... | .... | .... |
| Mukden | .... | .... | .... | .... | .... | 1 | .... | .... | .... | .... | .... |
| Bulk $F_3$ generation | .... | .... | .... | .... | 1 | .... | .... | .... | .... | .... | .... |
| Manchuria 13-177 x Richland (Cross 2715) | 1 | 1 | 6 | 7 | 11 | 15 | 27 | 6 | 1 | 2 | .... |
| Richland | .... | 1 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Manchuria 13-177 | .... | .... | .... | .... | .... | .... | 1 | .... | .... | .... | .... |
| Bulk $F_3$ generation | .... | .... | .... | .... | .... | .... | .... | 1 | .... | .... | .... |
| P. I. 79885 x Richland (Cross 3515) | 3 | 3 | 6 | 22 | 9 | 17 | 11 | 4 | .... | 1 | 1 |
| Richland | .... | 1 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| P. I. 79885 | .... | .... | .... | .... | .... | .... | 1 | .... | .... | .... | .... |
| Bulk $F_3$ generation | .... | .... | .... | .... | .... | .... | 1 | .... | .... | .... | .... |
| P. I. 89009-2 x Richland (Cross 3715) | 3 | 1 | 6 | 8 | 11 | 27 | 18 | 3 | .... | .... | .... |
| Richland | .... | 1 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| P. I. 89009-2 | .... | .... | .... | .... | .... | 1 | .... | .... | .... | .... | .... |
| Bulk $F_3$ generation | .... | .... | .... | .... | .... | .... | 1 | .... | .... | .... | .... |

as recorded in table 21, showed that only a few lines in each cross had lodging scores as low as or lower than Richland. A number of lines, however, exhibited more lodging resistance than the other parents. Transgressive segregation for factors causing poor lodging resistance was somewhat more in evidence than transgressive segregation for factors causing good lodging resistance. Of the four crosses, crosses 1415 and 3515 had the most lines with small lodging scores. Cross 2715, on the other hand, had the most lines with large lodging scores. These proportions were corroborated by the average lodging scores for all entries in each of the crosses, as shown in table 22. These results, in turn, agreed with those obtained in bulk population trials of the same crosses, where cross 1415 had the lowest and cross 2715 the highest average lodging score.

Analyses of variance of lodging scores of the $F_3$ lines, parents and bulk generations in each of the crosses are found in table 22. Differences in mean lodging scores among $F_3$ lines were highly significant in all cases. F values for line mean squares, however, did not approach the magnitude of the comparable ones for maturity and height. The high coefficients of variation of the lodging scores indicated that lodging scores probably were not evaluated as accurately as maturity and height in this test. Improvements in lodging resistance over that of the more lodging susceptible parents, nevertheless, seemed a definite possibility on the basis of these results.

## CORRELATIONS

It was shown by analyses of variance that differences in mean yield, maturity and height among $F_3$ lines of each cross studied were highly significant with but one exception. Each $F_3$ line was the

TABLE 22. ANALYSES OF VARIANCE OF LODGING SCORES OF 77 $F_3$ LINES, PARENTS AND BULK $F_2$ AND $F_3$ GENERATIONS IN EACH OF FOUR SOYBEAN CROSSES.

| Source of variation | D. F. | Mean squares | | | |
|---|---|---|---|---|---|
| | | Mukden x Richland (Cross 1415) | Manchuria 13-177 x Richland (Cross 2715) | P. I. 79885 x Richland (Cross 3515) | P. I. 89009-2 x Richland (Cross 3715) |
| Replications | 2 | 20.17 | 2.01 | 1.39 | 14.82 |
| Blocks (eliminating lines) | 24 | 0.37 | 0.29 | 0.32 | 0.37 |
| Lines (ignoring blocks) | 80 | 0.98* | 0 93* | 1.07* | 0.76* |
| Error (intrablock) | 136 | 0.24 | 0 20 | 0.18 | 0.19 |
| Error (randomized complete block) | 160 | 0.26 | 0 21 | 0.20 | 0.21 |
| General mean lodging score | ... | 2.3 | 2.6 | 2.3 | 2.5 |
| Precision | ... | 104.0% | 101.9% | 105 3% | 105.0% |
| Coefficient of variation | ... | 21.7% | 17.5% | 19.0% | 18.0% |
| Average standard error of a difference (lodging score) | ... | .4 | .4 | .4 | .4 |

*Significant at the 1 percent level.

TABLE 23. PARENT PLANT-PROGENY CORRELATIONS OF YIELDS, PLANT HEIGHTS AND MATURITIES OF 77 $F_2$ PLANTS AND THE MEANS OF THEIR REPLICATED PROGENIES IN EACH OF FOUR SOYBEAN CROSSES.

| Variates correlated | D. F. | Mukden x Richland (Cross 1415) | Manchuria 13-177 x Richland (Cross 2715) | P. I. 79885 x Richland (Cross 3515) | P. I. 89009-2 x Richland (Cross 3715) |
|---|---|---|---|---|---|
| $F_2$ plant yield and $F_3$ mean yield | 75 | .37* | .07 | 22 | .30* |
| $F_2$ plant height and $F_3$ mean height | 75 | .65* | .70* | 72* | .82* |
| $F_2$ plant maturity and $F_3$ mean maturity | 75 | .84* | .88* | .86* | .79* |

*P less than 0.01.

progeny of a single $F_2$ plant grown the previous year and measured for the same agronomic characters. The degree of association between the $F_2$ plants and their descendant $F_3$ lines for these characters was measured by means of the correlation coefficient. These plant-progeny correlations for each cross appear in table 23. Two of the four correlations for yield were highly significant. They were so small, however, that most of the variation among $F_3$ means was not attributable to regression. Correlations for maturity and for height, on the other hand, all were highly significant and large enough so that a considerable proportion of the variation among $F_3$ means was due to regression. Differences in yield among $F_2$ plants in these crosses, therefore, were of little or no value as a basis for selecting high yielding progenies. Breeding behavior for maturity and height, on the contrary, was reasonably consistent during the $F_2$ and $F_3$ generations.

## $F_4$ LINE TEST

Visible genetic segregation for agronomic characters generally continues through the $F_4$ or $F_5$ and sometimes the $F_6$ generation following hybridization in self-pollinated crops. In the $F_6$ generation pedigree lines usually are pure enough to be bulked for subsequent yield testing. It has been suggested by some breeders, however, that the genetic factors conditioning yield and other agronomic characters in soybeans are stable enough by the $F_3$ or $F_4$ generation to merit the evaluation of lines for these characters in replicated trials. If true this procedure could be used to eliminate low-yielding lines earlier than usual in the breeding program and thereby make more time available for selection in the more promising material in subsequent generations.

A substantial amount of genetic segregation for agronomic characters among $F_2$ plants in the soybean crosses included in this study was indicated by their progeny tests in the $F_3$ generation in 1945. The extent of segregation among $F_3$ plants was studied by growing $F_3$ progenies in a replicated test in the $F_4$ generation in 1946. Selection of lines was based on yield distributions of $F_3$ lines in 1945. In all, 15 $F_3$ lines were selected from the yield distributions of each of the crosses. Each $F_3$ line thus selected was represented in the $F_4$ generation by the progenies of five of its $F_3$ plants. The parents and bulk $F_3$, $F_4$ and $F_5$ generations also were incorporated in the test for each cross, thereby making a total of 80 entries per cross. This procedure made it possible to analyze agronomic differences among $F_4$ lines within $F_3$ families and among the progenies of $F_3$ families within each cross. In addition, it provided a means for continuing the study of breeding behavior at successive generations.

### SEED YIELD

Yields of the $F_4$ lines, parents and bulk generations in each cross were obtained on single 8-foot rows replicated three times in a randomized split plot design in 1946. $F_3$ families constituted the whole plots and $F_4$ lines within $F_3$ families the subplots in the experimental design. Each replication also was randomized on a whole cross basis. Mean yields of $F_4$ lines, parents and bulk generations in each of the four crosses in comparison with yields of the parental $F_2$ plants and $F_3$ lines in 1944 and 1945, respectively, appear in tables 24 to 27. These yield data show several noteworthy features. First, most yield differences among $F_4$ lines within each $F_3$ family were relatively small. Second, the range in yield of the progenies of $F_3$ families, as an average of the five $F_4$ lines in each, was considerably smaller than the range in yield of the parental $F_3$ lines in 1945. A third point of interest was the yield performance of the three bulk generations in each cross, as compared to the two parents. All three bulk generations of cross 1415 yielded more than either parent. Their average yield superiority was 2.3 bushels per acre above Mukden, the higher yielding parent. In the other three crosses, however, only the bulk $F_3$ generation of cross 3715 outyielded either parent, while all others were intermediate to the parents. If these bulk generation yields were indicative of the continued manifestations of the degree of heterosis, they were distinctly contradictory to the results obtained in the $F_1$ generation spaced plant study (see table 1). In that study cross 1415 showed the least amount of heterosis of the four crosses.

Analyses of variance of yields obtained in the 1946 test are given in table 28. They offer further confirmation of some of the statements made in the previous paragraph. In only one of the crosses, namely, cross 3515, were differences between the $F_3$ family progenies statistically significant. Yield differences among the parental $F_3$ lines were highly significant for every cross but cross 3715 in 1945. In 1946 this cross had the lowest F value of the four crosses for its mean square of the $F_3$ family progenies. Average yield differences among $F_4$ lines within $F_3$ families were highly significant for each cross. Only a few of the individual mean squares for $F_4$ lines within $F_3$ families, however, were significant when tested against the pooled subplot error mean square.

Analyses of the 1946 yield data indicated a tendency for the means of $F_3$ family progenies to regress toward the cross means. Part of this tendency was no doubt due to the small plot size and number of replications in the $F_3$ line test in 1945, which probably resulted in some inaccuracies in the yield evaluations of $F_3$ lines. Furthermore, five $F_4$ lines constituted a very small sample of the total possible number of lines that could have been selected to represent the progeny of each $F_3$ family. It also would have been preferable to have had larger plots and more replications in the 1946 test. It was practically impossible, however, to correct these shortcomings because of the definite limitations on seed from individual plants.

TABLE 24. YIELDS OF $F_2$ PLANTS IN 1944 AND MEAN YIELDS OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 1415 (MUKDEN X RICHLAND), TOGETHER WITH YIELDS OF PARENTS AND THREE BULK GENERATIONS IN 1946.

| Cross and $F_2$ plant number | $F_2$ plant (Yield in grams) | $F_3$ line (Bushels per acre) | $F_4$ lines (Bushels per acre) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | Mean |
| 1415–22 | 68 | 43.9 | 34.4 | 35.1 | 37.0 | 30.4 | 35.0 | 34.4 |
| 1415–25 | 56 | 48.7 | 36.5 | 35.5 | 36.4 | 35.4 | 34.2 | 35.6 |
| 1415–29 | 48 | 47.1 | 33.1 | 33.0 | 35.2 | 33.3 | 35.9 | 34.1 |
| 1415–30 | 57 | 50.0 | 37.4 | 36.2 | 36.1 | 31.5 | 36.4 | 35.5 |
| 1415–32 | 50 | 43.0 | 32.5 | 32.3 | 36.3 | 36.8 | 35.0 | 34.6 |
| 1415–42 | 64 | 45.3 | 34.5 | 33.5 | 37.6 | 33.3 | 36.7 | 35 1 |
| 1415–44 | 48 | 46.1 | 33.8 | 32.2 | 31.7 | 32.4 | 29.3 | 31.9 |
| 1415–50 | 52 | 47.7 | 34.6 | 35.0 | 36.3 | 35.7 | 35.9 | 35.5 |
| 1415–56 | 40 | 45.0 | 33.2 | 33.2 | 32.9 | 32.6 | 33.3 | 33.0 |
| 1415–57 | 32 | 44.2 | 36.2 | 35.8 | 36.8 | 37.7 | 37.2 | 36.7 |
| 1415–60 | 37 | 39.9 | 33.3 | 33.8 | 34.7 | 30.6 | 34.9 | 33.4 |
| 1415–63 | 54 | 42.7 | 33.6 | 39.6 | 36.5 | 36.6 | 33.5 | 35.9 |
| 1415–72 | 30 | 41.6 | 33.3 | 31.1 | 33.5 | 33.6 | 33.2 | 32.9 |
| 1415–74 | 72 | 45.5 | 36.0 | 29.5 | 33.2 | 39.0 | 35.9 | 34.7 |
| 1415–77 | 47 | 40.4 | 29.9 | 31.2 | 28.7 | 32.6 | 31.8 | 30.8 |

| Mukden | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 32.7 | 31.9 | 36.1 | 32.9 | 36.0 |

Mean yield of all entries in 1946 test
34.3

TABLE 25. YIELDS OF $F_2$ PLANTS IN 1944 AND MEAN YIELDS OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 2715 (MANCHURIA 13-177 X RICHLAND), TOGETHER WITH YIELDS OF PARENTS AND THREE BULK GENERATIONS IN 1946.

| Cross and $F_2$ plant number | $F_2$ plant (Yield in grams) | $F_3$ line (Bushels per acre) | $F_4$ lines (Bushels per acre) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | Mean |
| 2715–4 | 39 | 44.1 | 38.5 | 38.2 | 29.9 | 37.9 | 37.9 | 36.5 |
| 2715–17 | 46 | 50.8 | 34.2 | 35.0 | 36.9 | 37.6 | 38.5 | 36.5 |
| 2715–23 | 72 | 46.3 | 36.9 | 37.5 | 37.2 | 41.7 | 38.5 | 38.4 |
| 2715–30 | 66 | 48.7 | 37.0 | 41.0 | 41.3 | 37.7 | 38.8 | 39.2 |
| 2715–31 | 37 | 39.7 | 35.9 | 35.6 | 35.5 | 36.9 | 37.2 | 36.2 |
| 2715–38 | 52 | 44.8 | 42.6 | 35.7 | 33.4 | 35.9 | 34.1 | 36.3 |
| 2715–40 | 57 | 53.3 | 37.0 | 33.6 | 37.0 | 36.3 | 38.5 | 36.5 |
| 2715–51 | 42 | 41.5 | 32.1 | 34.2 | 33.9 | 37.5 | 31.9 | 33.9 |
| 2715–56 | 45 | 44 1 | 31.4 | 34.0 | 33.8 | 35.9 | 37.3 | 34.5 |
| 2715–58 | 70 | 47.3 | 31.0 | 32.3 | 36.4 | 37.2 | 29.7 | 33.3 |
| 2715–63 | 55 | 42.6 | 40.3 | 38.7 | 39.1 | 40.1 | 38.2 | 39.3 |
| 2715–72 | 62 | 50.1 | 35.0 | 35.7 | 32.7 | 35.7 | 32.1 | 34.3 |
| 2715–76 | 46 | 43.7 | 40.3 | 37.8 | 35.2 | 38.5 | 34.7 | 37.3 |
| 2715–78 | 26 | 45.4 | 34.8 | 34.1 | 33.5 | 31.2 | 33.9 | 33.5 |
| 2715–80 | 25 | 42.8 | 36.5 | 35.0 | 36.3 | 34.9 | 34.1 | 35.3 |

| Manchuria 13-177 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 40.3 | 35.2 | 38.8 | 40.2 | 36.9 |

Mean yield of all entries in 1946 test
36.2

TABLE 26. YIELDS OF $F_2$ PLANTS IN 1944 AND MEAN YIELDS OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 3515 (P. I. 79885 X RICHLAND), TOGETHER WITH YIELDS OF PARENTS AND THREE BULK GENERATIONS IN 1946.

| Cross and $F_2$ plant number | $F_2$ plant (Yield in grams) | $F_3$ line (Bushels per acre) | $F_4$ lines (Bushels per acre) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | Mean |
| 3515–3 | 36 | 50.8 | 36.2 | 38 1 | 33.6 | 37.0 | 36.4 | 36.3 |
| 3515–16 | 34 | 49.4 | 37 6 | 37.3 | 39.7 | 36.7 | 37.5 | 37 8 |
| 3515–18 | 33 | 45.1 | 37.3 | 39.9 | 35.8 | 38 7 | 39.1 | 38.2 |
| 3515–29 | 70 | 51 7 | 35.5 | 32.7 | 38.1 | 33 7 | 29 5 | 33.9 |
| 3515–37 | 36 | 53.2 | 37.5 | 39.3 | 37.3 | 35.6 | 35.3 | 37.0 |
| 3515–44 | 47 | 46.3 | 33.5 | 37.5 | 34.1 | 32 2 | 39 0 | 35.3 |
| 3515–51 | 42 | 41 3 | 36.9 | 35 8 | 36.0 | 36.1 | 33.9 | 35.7 |
| 3515–67 | 37 | 49.7 | 36.4 | 34.8 | 35 1 | 36.6 | 36.4 | 35.8 |
| 3515–68 | 61 | 47.1 | 32.5 | 17.3 | 36 5 | 33 1 | 36.4 | 31.2 |
| 3515–73 | 41 | 47.9 | 35.8 | 33.7 | 39.0 | 38 5 | 34.0 | 36.2 |
| 3515–82 | 48 | 45 9 | 37.5 | 34.5 | 35 2 | 37.0 | 38.4 | 36.5 |
| 3515–88 | 42 | 46.5 | 34 0 | 32.4 | 27.8 | 32.5 | 33.9 | 32.1 |
| 3515–93 | 37 | 48.4 | 34 5 | 34 5 | 33.0 | 36 3 | 34.0 | 34.5 |
| 3515–95 | 31 | 43 4 | 31.4 | 35 4 | 39 1 | 38.2 | 36.4 | 36.7 |
| 3515–98 | 44 | 50 2 | 35.3 | 33 8 | 34.8 | 35.2 | 32.6 | 34.3 |

| P. I. 79885 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 37.0 | 32.5 | 35.6 | 34.5 | 34.5 |

Mean yield of all entries in 1946 test
35.4

TABLE 27. YIELDS OF $F_2$ PLANTS IN 1944 AND MEAN YIELDS OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 3715 (P. I. 89009-2 X RICHLAND), TOGETHER WITH YIELDS OF PARENTS AND THREE BULK GENERATIONS IN 1946.

| Cross and $F_2$ plant number | $F_2$ plant (Yield in grams) | $F_3$ line (Bushels per acre) | $F_4$ lines (Bushels per acre) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | Mean |
| 3715–15 | 44 | 37.0 | 36.5 | 32.8 | 33.5 | 34.6 | 35.8 | 34.6 |
| 3715–18 | 29 | 40 5 | 39.0 | 34.4 | 39.1 | 38.2 | 38 4 | 37.8 |
| 3715–20 | 56 | 41.9 | 36 6 | 34.3 | 32.9 | 36.6 | 31.8 | 34.4 |
| 3715–23 | 29 | 42.5 | 31 8 | 31.2 | 31.4 | 35.0 | 31.9 | 32.3 |
| 3715–25 | 43 | 42.8 | 35.7 | 37.2 | 30.1 | 35.2 | 36.2 | 34.9 |
| 3715–26 | 42 | 40.9 | 34.5 | 32.0 | 32.4 | 29.4 | 30 9 | 31.8 |
| 3715–39 | 48 | 37.6 | 31.8 | 34.4 | 31.8 | 38.1 | 28.1 | 32.9 |
| 3715–48 | 30 | 39.5 | 32.6 | 31.0 | 31 8 | 33 8 | 34.6 | 32.8 |
| 3715–53 | 70 | 39.6 | 33.7 | 33.2 | 36.0 | 35 9 | 33.4 | 34.4 |
| 3715–68 | 32 | 35.7 | 32.0 | 37.1 | 37.8 | 33.5 | 33.8 | 34.8 |
| 3715–73 | 55 | 44 4 | 31 7 | 35.9 | 36.4 | 39.3 | 35 9 | 35 8 |
| 3715–76 | 87 | 44 8 | 32 6 | 39.4 | 32.2 | 34 2 | 34 8 | 34.7 |
| 3715–80 | 59 | 38.3 | 33.6 | 32.2 | 37.2 | 34 4 | 34.3 | 34.3 |
| 3715–83 | 39 | 40.1 | 36.3 | 34.7 | 37.1 | 36.5 | 36.8 | 36.3 |
| 3715–96 | 82 | 41.8 | 33.1 | 34.0 | 34.4 | 33.7 | 34 5 | 33.9 |

| P. I. 89009-2 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 36.9 | 32 2 | 37 1 | 35 6 | 36 3 |

Mean yield of all entries in 1946 test
34.5

TABLE 28. ANALYSES OF VARIANCE OF YIELDS OBTAINED IN 1946 TESTS OF $F_4$ LINES, PARENTS AND BULK POPULATIONS IN EACH OF FOUR SOYBEAN CROSSES.

| Source of variation | D. F. | Mukden x Richland | | Manchuria 13-177 x Richland | | P. I. 79885 x Richland | | P. I. 89009-2 x Richland | |
|---|---|---|---|---|---|---|---|---|---|
| | | Cross and $F_2$ plant number | Mean square | Cross and $F_2$ plant number | Mean square | Cross and $F_2$ plant number | Mean square | Cross and $F_2$ plant number | Mean square |
| WHOLE PLOT: | | | | | | | | | |
| Replications | 2 | ... | 750.90 | ... | 50.58 | ... | 663.63 | ... | 194.26 |
| $F_3$ family progenies | 15 | ... | 36.38 | ... | 56.99 | ... | 53.78** | ... | 35.80 |
| Error (a) | 30 | ... | 20.64 | ... | 31.40 | ... | 14.98 | ... | 26.59 |
| SUBPLOT: | | | | | | | | | |
| $F_4$ lines within $F_3$ families | 64 | ... | 10.37** | ... | 14.96** | ... | 22.02** | ... | 13.56** |
| | 4 | 1415–22 | 17.58* | 2715–4 | 40.92** | 3515–3 | 8.27 | 3715–15 | 7.10 |
| | 4 | " –25 | 2.52 | " –17 | 9.59 | " –16 | 3.87 | " –18 | 11.40 |
| | 4 | " –29 | 5.41 | " –23 | 11.40 | " –18 | 7.68 | " –20 | 13.90* |
| | 4 | " –30 | 16.06* | " –30 | 10.81 | " –29 | 30.84** | " –23 | 7.16 |
| | 4 | " –32 | 13.30* | " –31 | 1.80 | " –37 | 7.99 | " –25 | 22.88** |
| | 4 | " –42 | 11.23 | " –38 | 40.16** | " –44 | 24.95** | " –26 | 10.39 |
| | 4 | " –44 | 7.86 | " –40 | 9.88 | " –51 | 3.54 | " –39 | 40.76** |
| | 4 | " –50 | 1.31 | " –51 | 15.11 | " –67 | 2.12 | " –48 | 6.40 |
| | 4 | " –56 | 0.25 | " –56 | 15.01 | " –68 | 190.00** | " –53 | 5.84 |
| | 4 | " –57 | 1.74 | " –58 | 33.36** | " –73 | 18.41* | " –68 | 18.93* |
| | 4 | " –60 | 8.94 | " –63 | 2.55 | " –82 | 7.73 | " –73 | 22.10** |
| | 4 | " –63 | 19.25** | " –72 | 9.03 | " –88 | 18.90* | " –76 | 24.74** |
| | 4 | " –72 | 3.27 | " –76 | 16.06* | " –93 | 4.45 | " –80 | 9.99 |
| | 4 | " –74 | 38.32** | " –78 | 5.78 | " –95 | 11.41 | " –83 | 2.50 |
| | 4 | " –77 | 7.20 | " –80 | 3.11 | " –98 | 3.94 | " –96 | 1.05 |
| Parents and bulks | 4 | | 11.72 | | 14.86 | | 8.31 | | 11.78 |
| Error (b) | 128 | ... | 5.07 | ... | 6.43 | ... | 6.70 | ... | 5.65 |

*Significant at the 5 percent level. **Significant at the 1 percent level.

Consequently, it would have been difficult to improve on the reliability of the conclusions drawn on the basis of these data.

## MATURITY

Mean maturities of $F_4$ lines, parents and bulk generations in each cross in 1946, as compared with the maturities of parental $F_2$ plants and $F_3$ lines in 1944 and 1945, respectively, are found in tables 29 to 32. In contrast to the yield data, the range in mean maturity of $F_3$ family progenies was greater for each cross in 1946 than the range in maturity of the parental $F_3$ lines in 1945. This result was due in part to weather conditions, as the early growing season in 1945 was too cool for rapid growth and caused maturities to be somewhat closer together than usual. The 1946 season was more favorable for normal growth and maturation. Maturities of bulk generations in each cross in 1946 reflected average differences among the crosses similar to those previously observed.

As shown by the analyses of variance in table 33, differences in maturity among $F_3$ family progenies were highly significant in each cross. The great majority of the differences among $F_4$ lines within each of the $F_3$ families also were highly significant. This would indicate that there was still considerable segregation for factors conditioning maturity among the $F_3$ lines which were progeny-tested in the $F_4$ generation.

TABLE 29. MATURITIES OF $F_2$ PLANTS IN 1944 AND MEAN MATURITIES OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 1415 (MUKDEN X RICHLAND), TOGETHER WITH MATURITIES OF PARENTS AND THREE BULK GENERATIONS IN 1946. (MATURITY IN NUMBER OF DAYS AFTER AUGUST 31)

| Cross and $F_2$ plant number | $F_2$ plant | $F_3$ line | $F_4$ lines | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | Mean |
| 1415–22 | 29 | 32 | 17 | 23 | 19 | 16 | 20 | 19 |
| 1415–25 | 25 | 32 | 21 | 20 | 23 | 19 | 19 | 20 |
| 1415–29 | 25 | 33 | 19 | 20 | 19 | 19 | 20 | 19 |
| 1415–30 | 26 | 31 | 24 | 26 | 26 | 15 | 17 | 22 |
| 1415–32 | 29 | 33 | 23 | 21 | 20 | 29 | 23 | 23 |
| 1415–42 | 28 | 34 | 19 | 14 | 22 | 19 | 20 | 19 |
| 1415–44 | 36 | 35 | 25 | 22 | 27 | 27 | 24 | 25 |
| 1415–50 | 24 | 31 | 19 | 21 | 16 | 18 | 19 | 19 |
| 1415–56 | 27 | 32 | 22 | 24 | 20 | 18 | 19 | 20 |
| 1415–57 | 17 | 30 | 23 | 14 | 18 | 18 | 17 | 18 |
| 1415–60 | 24 | 32 | 20 | 21 | 20 | 15 | 14 | 18 |
| 1415–63 | 19 | 30 | 16 | 20 | 18 | 22 | 16 | 18 |
| 1415–72 | 22 | 31 | 20 | 16 | 22 | 17 | 22 | 19 |
| 1415–74 | 27 | 35 | 15 | 8 | 20 | 25 | 19 | 18 |
| 1415–77 | 24 | 33 | 19 | 16 | 18 | 18 | 19 | 18 |

| Mukden | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 25 | 17 | 23 | 24 | 22 |

Mean maturity of all entries in 1946 test
20

TABLE 30. MATURITIES OF $F_2$ PLANTS IN 1944 AND MEAN MATURITIES OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 2715 (MANCHURIA 13-177 X RICHLAND), TOGETHER WITH MATURITIES OF PARENTS AND THREE BULK GENERATIONS IN 1946. (MATURITY IN NUMBER OF DAYS AFTER AUGUST 31)

| Cross and $F_2$ plant number | $F_2$ plant | $F_3$ line | $F_4$ lines 1 | 2 | 3 | 4 | 5 | Mean |
|---|---|---|---|---|---|---|---|---|
| 2715–4 | 16 | 32 | 25 | 27 | 8 | 23 | 32 | 23 |
| 2715–17 | 17 | 27 | 18 | 12 | 15 | 19 | 25 | 18 |
| 2715–23 | 32 | 42 | 21 | 27 | 39 | 35 | 27 | 30 |
| 2715–30 | 20 | 34 | 25 | 24 | 30 | 29 | 28 | 27 |
| 2715–31 | 16 | 31 | 20 | 18 | 17 | 19 | 19 | 19 |
| 2715–38 | 32 | 42 | 33 | 39 | 29 | 25 | 39 | 33 |
| 2715–40 | 21 | 30 | 19 | 13 | 24 | 23 | 21 | 20 |
| 2715–51 | 35 | 41 | 42 | 27 | 27 | 32 | 31 | 32 |
| 2715–56 | 27 | 32 | 15 | 21 | 16 | 24 | 18 | 19 |
| 2715–58 | 42 | 42 | 44 | 38 | 26 | 33 | 50 | 38 |
| 2715–63 | 38 | 42 | 30 | 37 | 38 | 29 | 32 | 33 |
| 2715–72 | 36 | 39 | 21 | 31 | 37 | 36 | 39 | 33 |
| 2715–76 | 30 | 40 | 24 | 37 | 13 | 23 | 40 | 27 |
| 2715–78 | 15 | 33 | 25 | 29 | 20 | 12 | 21 | 21 |
| 2715–80 | 23 | 41 | 31 | 37 | 31 | 37 | 33 | 34 |

| Manchuria 13-177 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 36 | 18 | 37 | 39 | 38 |

Mean maturity of all entries in 1946 test
27

TABLE 31. MATURITIES OF $F_2$ PLANTS IN 1944 AND MEAN MATURITIES OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 3515 (P. I. 79885 X RICHLAND), TOGETHER WITH MATURITIES OF PARENTS AND THREE BULK GENERATIONS IN 1946. (MATURITY IN NUMBER OF DAYS AFTER AUGUST 31)

| Cross and $F_2$ plant number | $F_2$ plant | $F_3$ line | $F_4$ lines 1 | 2 | 3 | 4 | 5 | Mean |
|---|---|---|---|---|---|---|---|---|
| 3515–3 | 16 | 30 | 14 | 16 | 12 | 15 | 14 | 14 |
| 3515–16 | 18 | 33 | 23 | 21 | 25 | 17 | 21 | 21 |
| 3515–18 | 26 | 38 | 24 | 25 | 23 | 25 | 22 | 24 |
| 3515–29 | 22 | 31 | 19 | 20 | 27 | 13 | 20 | 20 |
| 3515–37 | 16 | 27 | 14 | 16 | 19 | 13 | 9 | 14 |
| 3515–44 | 17 | 29 | 16 | 19 | 13 | 11 | 23 | 17 |
| 3515–51 | 17 | 32 | 23 | 15 | 20 | 28 | 15 | 20 |
| 3515–67 | 17 | 33 | 22 | 22 | 17 | 21 | 20 | 20 |
| 3515–68 | 26 | 38 | 23 | 32 | 27 | 22 | 29 | 27 |
| 3515–73 | 27 | 37 | 18 | 28 | 24 | 20 | 30 | 24 |
| 3515–82 | 16 | 30 | 20 | 24 | 18 | 15 | 17 | 19 |
| 3515–88 | 23 | 34 | 18 | 27 | 26 | 21 | 13 | 21 |
| 3515–93 | 31 | 38 | 26 | 22 | 21 | 30 | 26 | 25 |
| 3515–95 | 17 | 34 | 22 | 26 | 28 | 20 | 18 | 23 |
| 3515–98 | 15 | 31 | 18 | 15 | 23 | 14 | 12 | 16 |

| P. I. 79885 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 18 | 16 | 21 | 25 | 24 |

Mean maturity of all entries in 1946 test
20

TABLE 32. MATURITIES OF $F_2$ PLANTS IN 1944 AND MEAN MATURITIES OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 3715 (P. I. 89009-2 X RICHLAND), TOGETHER WITH MATURITIES OF PARENTS AND THREE BULK GENERATIONS IN 1946. (MATURITY IN NUMBER DAYS AFTER AUGUST 31)

| Cross and $F_2$ plant number | $F_2$ plant | $F_3$ line | $F_4$ lines | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | Mean |
| 3715–15 | 29 | 38 | 29 | 30 | 27 | 32 | 28 | 29 |
| 3715–18 | 29 | 41 | 27 | 28 | 34 | 34 | 35 | 32 |
| 3715–20 | 28 | 37 | 32 | 29 | 25 | 30 | 33 | 30 |
| 3715–23 | 26 | 36 | 19 | 18 | 20 | 19 | 22 | 20 |
| 3715–25 | 30 | 41 | 28 | 34 | 13 | 29 | 35 | 28 |
| 3715–26 | 27 | 39 | 30 | 30 | 32 | 27 | 17 | 27 |
| 3715–39 | 40 | 41 | 25 | 27 | 28 | 36 | 30 | 29 |
| 3715–48 | 17 | 33 | 21 | 19 | 25 | 27 | 23 | 23 |
| 3715–53 | 27 | 39 | 40 | 37 | 37 | 32 | 38 | 37 |
| 3715–68 | 30 | 42 | 17 | 37 | 31 | 33 | 35 | 31 |
| 3715–73 | 32 | 40 | 13 | 31 | 33 | 37 | 26 | 28 |
| 3715–76 | 27 | 40 | 15 | 36 | 14 | 11 | 10 | 18 |
| 3715–80 | 30 | 41 | 29 | 28 | 33 | 25 | 16 | 26 |
| 3715–83 | 30 | 41 | 30 | 15 | 30 | 34 | 36 | 29 |
| 3715–96 | 37 | 40 | 28 | 28 | 31 | 30 | 30 | 29 |

| P. I. 89009-2 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 28 | 16 | 34 | 35 | 35 |

Mean maturity of all entries in 1946 test
28

HEIGHT

Mean plant heights for the 1946 test of $F_4$ lines, parents and bulk generations in each cross appear in tables 34 to 37. Heights of parental $F_2$ plants and $F_3$ lines in 1944 and 1945, respectively, also are included. These results showed that differences in height among $F_4$ lines in each $F_3$ family of the four crosses were very similar to differences in maturity among the same lines. In a few $F_3$ families their progenies in the $F_4$ generation were reasonably uniform for plant height. Most of them, however, were quite variable, as indicated by their breeding behavior for height. In addition, the average heights of the $F_3$ family progenies in 1946 exhibited height ranges of about the same extent as the parental $F_3$ lines in 1945.

Mean heights of the bulk populations in each cross in this test were consistent with previous observations. Bulk generations of cross 3715 again were definitely above Richland, the taller parent, in height. Bulk populations of the other crosses were intermediate to the parents in height except in cross 2715, where they equalled the taller parent. Mean heights of all entries in each of the four crosses indicated that crosses 1415 and 2715 contained the greatest number of tall $F_4$ lines. Cross 3515, on the other hand, contained the most short $F_4$ lines. These means were comparable because $F_3$ families included in the test were unselected for plant height.

Table 38 gives the analyses of variance of plant heights in 1946.

TABLE 33. ANALYSES OF VARIANCE OF MATURITIES OBTAINED IN 1946 TEST OF $F_4$ LINES, PARENTS AND BULK POPULATIONS IN EACH OF FOUR SOYBEAN CROSSES.

| Source of variation | D. F. | Mukden x Richland | | Manchuria 13-177 x Richland | | P. I. 79885 x Richland | | P. I. 89009-2 x Richland | |
|---|---|---|---|---|---|---|---|---|---|
| | | Cross and $F_2$ plant number | Mean square | Cross and $F_2$ plant number | Mean square | Cross and $F_2$ plant number | Mean square | Cross and $F_2$ plant number | Mean square |
| WHOLE PLOT: | | | | | | | | | |
| Replications | 2 | ........... | 85.72 | ........... | 45.73 | ........... | 351.91 | ........... | 92.27 |
| $F_3$ family progenies | 15 | ........... | 72.31** | ........... | 671.60** | ........... | 204.59** | ........... | 317.76** |
| Error (a) | 30 | ........... | 7.73 | ........... | 10.33 | ........... | 9.54 | ........... | 3.98 |
| SUBPLOT: | | | | | | | | | |
| $F_4$ lines within $F_3$ families | 64 | ........... | 29.44** | ........... | 129.96** | ........... | 48.81** | ........... | 115.64** |
| | 4 | 1415–22 | 20.33** | 2715–4 | 255.33** | 3515–3 | 6.43* | 3715–15 | 9.23** |
| | 4 | " –25 | 6.33** | " –17 | 69.73** | " –16 | 26.27** | " –18 | 39.57** |
| | 4 | " –29 | 0.83 | " –23 | 150.50** | " –18 | 6.43* | " –20 | 34.43** |
| | 4 | " –30 | 80.90** | " –30 | 16.73** | " –29 | 74.40** | " –23 | 5.43** |
| | 4 | " –32 | 40.07** | " –31 | 3.57 | " –37 | 38.00** | " –25 | 240.57** |
| | 4 | " –42 | 27.57** | " –38 | 120.40** | " –44 | 69.10** | " –26 | 112.43** |
| | 4 | " –44 | 10.33** | " –40 | 63.83** | " –51 | 92.57** | " –39 | 48.23** |
| | 4 | " –50 | 7.73** | " –51 | 110.77** | " –67 | 11.07** | " –48 | 29.23** |
| | 4 | " –56 | 16.77** | " –56 | 42.17** | " –68 | 55.57** | " –53 | 27.23** |
| | 4 | " –57 | 30.23** | " –58 | 267.43** | " –73 | 78.00** | " –68 | 178.83** |
| | 4 | " –60 | 31.60** | " –63 | 52.40** | " –82 | 37.73** | " –73 | 249.23** |
| | 4 | " –63 | 21.07** | " –72 | 155.43** | " –88 | 96.67** | " –76 | 344.10** |
| | 4 | " –72 | 24.23** | " –76 | 384.57** | " –93 | 41.17** | " –80 | 127.00** |
| | 4 | " –74 | 118.90** | " –78 | 118.10** | " –95 | 54.77** | " –83 | 196.23** |
| | 4 | " –77 | 3.83* | " –80 | 28.90** | " –98 | 53.60** | " –96 | 4.57* |
| Parents and bulks | 4 | ........... | 30.23** | ........... | 239.43** | ........... | 39.17** | ........... | 203.90** |
| Error (b) | 128 | ........... | 1.57 | ........... | 1.79 | ........... | 2.26 | ........... | 1.46 |

*Significant at the 5 percent level. **Significant at the 1 percent level.

TABLE 34. HEIGHTS OF $F_2$ PLANTS IN 1944 AND MEAN HEIGHTS OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 1415 (MUKDEN X RICHLAND), TOGETHER WITH HEIGHTS OF PARENTS AND THREE BULK GENERATIONS IN 1946.

| Cross and $F_2$ plant number | $F_2$ plant (Height in inches) | $F_3$ line (Height in inches) | $F_4$ lines (Heights in inches) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | Mean |
| 1415–22 | 34 | 38 | 35 | 40 | 39 | 36 | 40 | 38 |
| 1415–25 | 36 | 40 | 40 | 40 | 41 | 38 | 40 | 40 |
| 1415–29 | 32 | 37 | 35 | 38 | 38 | 36 | 39 | 37 |
| 1415–30 | 40 | 41 | 44 | 40 | 37 | 36 | 35 | 38 |
| 1415–32 | 31 | 39 | 38 | 36 | 40 | 41 | 36 | 38 |
| 1415–42 | 34 | 33 | 37 | 30 | 33 | 34 | 37 | 34 |
| 1415–44 | 39 | 38 | 41 | 36 | 37 | 38 | 40 | 38 |
| 1415–50 | 35 | 40 | 40 | 39 | 35 | 36 | 36 | 37 |
| 1415–56 | 35 | 39 | 41 | 38 | 40 | 42 | 37 | 40 |
| 1415–57 | 32 | 35 | 36 | 33 | 35 | 35 | 38 | 35 |
| 1415–60 | 36 | 41 | 41 | 41 | 41 | 39 | 36 | 40 |
| 1415–63 | 28 | 36 | 37 | 35 | 37 | 37 | 34 | 36 |
| 1415–72 | 35 | 37 | 34 | 32 | 39 | 37 | 38 | 36 |
| 1415–74 | 38 | 38 | 36 | 27 | 37 | 33 | 41 | 35 |
| 1415–77 | 30 | 33 | 32 | 29 | 31 | 32 | 32 | 31 |

| Mukden | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 41 | 33 | 38 | 37 | 39 |

Mean height of all entries in 1946 test
37

TABLE 35. HEIGHTS OF $F_2$ PLANTS IN 1944 AND MEAN HEIGHTS OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 2715 (MANCHURIA 13-177 X RICHLAND), TOGETHER WITH HEIGHTS OF PARENTS AND THREE BULK GENERATIONS IN 1946.

| Cross and $F_2$ plant number | $F_2$ plant (Height in inches) | $F_3$ line (Height in inches) | $F_4$ lines (Heights in inches) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | Mean |
| 2715–4 | 29 | 34 | 35 | 36 | 28 | 34 | 35 | 34 |
| 2715–17 | 33 | 33 | 33 | 31 | 31 | 33 | 37 | 33 |
| 2715–23 | 42 | 39 | 37 | 37 | 41 | 39 | 40 | 39 |
| 2715–30 | 37 | 37 | 35 | 37 | 35 | 37 | 36 | 36 |
| 2715–31 | 35 | 35 | 37 | 36 | 37 | 37 | 37 | 37 |
| 2715–38 | 36 | 38 | 36 | 44 | 35 | 36 | 38 | 38 |
| 2715–40 | 32 | 34 | 34 | 30 | 35 | 39 | 34 | 34 |
| 2715–51 | 38 | 38 | 40 | 35 | 36 | 38 | 40 | 38 |
| 2715–56 | 35 | 36 | 32 | 36 | 35 | 35 | 35 | 34 |
| 2715–58 | 38 | 38 | 39 | 37 | 35 | 37 | 42 | 38 |
| 2715–63 | 36 | 36 | 40 | 41 | 39 | 39 | 41 | 40 |
| 2715–72 | 32 | 37 | 32 | 35 | 37 | 37 | 39 | 36 |
| 2715–76 | 36 | 35 | 36 | 39 | 33 | 35 | 40 | 37 |
| 2715–78 | 32 | 36 | 36 | 40 | 35 | 33 | 36 | 36 |
| 2715–80 | 35 | 36 | 40 | 42 | 39 | 43 | 41 | 41 |

| Manchuria 13-177 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 38 | 32 | 38 | 38 | 39 |

Mean height of all entries in 1946 test
37

TABLE 36. HEIGHTS OF $F_2$ PLANTS IN 1944 AND MEAN HEIGHTS OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 3515 (P. I. 79885 X RICHLAND), TOGETHER WITH HEIGHTS OF PARENTS AND THREE BULK GENERATIONS IN 1946.

| Cross and $F_2$ plant number | $F_2$ plant (Height in inches) | $F_3$ line (Height in inches) | $F_4$ lines (Heights in inches) 1 | 2 | 3 | 4 | 5 | Mean |
|---|---|---|---|---|---|---|---|---|
| 3515–3 | 17 | 27 | 28 | 29 | 28 | 27 | 26 | 27 |
| 3515–16 | 16 | 32 | 28 | 30 | 34 | 29 | 31 | 30 |
| 3515–18 | 27 | 33 | 32 | 32 | 32 | 34 | 33 | 32 |
| 3515–29 | 23 | 30 | 32 | 30 | 26 | 28 | 26 | 29 |
| 3515–37 | 16 | 30 | 29 | 26 | 27 | 26 | 26 | 27 |
| 3515–44 | 26 | 30 | 31 | 31 | 28 | 29 | 32 | 30 |
| 3515–51 | 25 | 32 | 31 | 30 | 30 | 32 | 29 | 31 |
| 3515–67 | 18 | 28 | 29 | 29 | 29 | 28 | 28 | 29 |
| 3515–68 | 32 | 34 | 36 | 24 | 38 | 34 | 38 | 34 |
| 3515–73 | 18 | 27 | 24 | 27 | 27 | 26 | 28 | 26 |
| 3515–82 | 27 | 33 | 33 | 32 | 34 | 29 | 34 | 32 |
| 3515–88 | 24 | 30 | 29 | 37 | 36 | 32 | 26 | 32 |
| 3515–93 | 29 | 37 | 36 | 34 | 38 | 39 | 37 | 37 |
| 3515–95 | 14 | 28 | 29 | 36 | 36 | 29 | 30 | 32 |
| 3515–98 | 33 | 34 | 33 | 34 | 36 | 33 | 31 | 34 |

| P. I. 79885 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 28 | 33 | 31 | 32 | 32 |

Mean height of all entries in 1946 test
31

TABLE 37. HEIGHTS OF $F_2$ PLANTS IN 1944 AND MEAN HEIGHTS OF THEIR PROGENIES IN $F_3$ IN 1945 AND OF FIVE $F_4$ GENERATION SELECTIONS PER $F_3$ LINE IN 1946 FOR CROSS 3715 (P. I. 89009-2 X RICHLAND), TOGETHER WITH HEIGHTS OF PARENTS AND THREE BULK GENERATIONS IN 1946.

| Cross and $F_2$ plant number | $F_2$ plant (Height in inches) | $F_3$ line (Height in inches) | $F_4$ lines (Height in inches) 1 | 2 | 3 | 4 | 5 | Mean |
|---|---|---|---|---|---|---|---|---|
| 3715–15 | 29 | 40 | 40 | 43 | 34 | 36 | 40 | 39 |
| 3715–18 | 32 | 37 | 37 | 39 | 35 | 29 | 39 | 36 |
| 3715–20 | 38 | 36 | 32 | 37 | 34 | 36 | 39 | 36 |
| 3715–23 | 31 | 35 | 33 | 33 | 33 | 35 | 34 | 34 |
| 3715–25 | 29 | 36 | 35 | 37 | 29 | 34 | 38 | 34 |
| 3715–26 | 38 | 39 | 41 | 41 | 42 | 39 | 36 | 40 |
| 3715–39 | 37 | 39 | 38 | 38 | 37 | 34 | 40 | 37 |
| 3715–48 | 32 | 32 | 32 | 32 | 33 | 34 | 34 | 33 |
| 3715–53 | 34 | 39 | 40 | 37 | 39 | 36 | 32 | 37 |
| 3715–68 | 32 | 38 | 27 | 37 | 36 | 22 | 37 | 32 |
| 3715–73 | 33 | 39 | 29 | 38 | 32 | 38 | 36 | 35 |
| 3715–76 | 37 | 39 | 30 | 34 | 29 | 31 | 30 | 31 |
| 3715–80 | 34 | 36 | 35 | 38 | 37 | 34 | 31 | 35 |
| 3715–83 | 32 | 37 | 34 | 27 | 36 | 31 | 37 | 33 |
| 3715–96 | 32 | 41 | 37 | 38 | 38 | 38 | 38 | 38 |

| P. I. 89009-2 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 30 | 33 | 36 | 37 | 37 |

Mean height of all entries in 1946 test
35

$F_3$ family progenies differed significantly in height in every instance. Average differences among $F_4$ lines within $F_3$ families in each of the crosses also were highly significant. Only a few of the $F_3$ families contained $F_4$ lines not significantly different among themselves in plant height. These results, like the comparable ones for maturity, indicated that the majority of the $F_3$ lines were heterozygous for genes conditioning plant height.

### LODGING SCORE

Differences in lodging resistance among $F_4$ lines in 1946 were quite large in many of the $F_3$ families included in this test, as shown by the lodging scores in tables 39 to 42. Lodging scores of only the parental $F_3$ lines in 1945 were included for comparison, as no lodging scores were taken on $F_2$ plants in 1944. These data conformed to expectations based on previous results. Crosses 1415 and 3515 again contained the most lines with good lodging resistance. Cross 2715, on the other hand, contained the most lines with poor lodging resistance. Mean lodging scores of bulk generations also indicated similar differences in lodging resistance among the crosses. Each of the crosses, nevertheless, contained $F_4$ lines worthy of selection for lodging resistance.

Analyses of variance of the lodging scores of $F_4$ lines, parents and bulk generations in 1946 showed that the $F_3$ family progenies in each of the crosses differed significantly for this character. These analyses (table 43) also indicated that most of the $F_3$ families in each cross consisted of $F_4$ lines significantly different among themselves for lodging resistance. Many parental $F_3$ lines, therefore, were heterozygous for factors affecting the amount of lodging.

### CORRELATIONS

Each group of five sister $F_4$ lines in the 1946 test descended from a single $F_2$ plant in 1944 and its progeny in the $F_3$ generation in 1945. In the previous section all correlations for maturity and height between $F_2$ plants and their progenies in the $F_3$ generation were highly significant. Similar correlations for yield were considered too small to be of value for selecting superior $F_2$ plants. Correlations between the $F_2$ and $F_4$ generations and between the $F_3$ and $F_4$ generations for these characters (table 44) showed the same general tendencies. Only two of the correlations for yield were significant. One of these, that between $F_2$ plants and the means of their $F_4$ lines in cross 3515, was significantly negative and thus quite contrary to expectation. The other significant correlation for yield was between $F_3$ plants and their $F_4$ lines in cross 1415. Individual $F_3$ plant data for this cross made it possible to calculate this correlation.

The most important group of yield correlations was that between the $F_3$ lines and their progeny $F_4$ lines. Three of these were very

TABLE 38. ANALYSES OF VARIANCE OF PLANT HEIGHTS OBTAINED IN 1946 TEST OF $F_4$ LINES, PARENTS AND BULK POPULATIONS IN EACH OF FOUR SOYBEAN CROSSES.

| Source of variation | D. F. | Mukden x Richland | | Manchuria 13-177 x Richland | | P. I. 79885 x Richland | | P. I. 89009-2 x Richland | |
|---|---|---|---|---|---|---|---|---|---|
| | | Cross and $F_2$ plant number | Mean square | Cross and $F_2$ plant number | Mean square | Cross and $F_2$ plant number | Mean square | Cross and $F_2$ plant number | Mean square |
| WHOLE PLOT: | | | | | | | | | |
| Replications | 2 | ........... | 146.74 | ........... | 90.52 | ........... | 8.41 | ........... | 32.66 |
| $F_3$ family progenies | 15 | ........... | 79.49** | ........... | 72.84** | ........... | 118.52** | ........... | 92.06** |
| Error (a) | 30 | ........... | 2.35 | ........... | 6.68 | ........... | 1.81 | ........... | 3.46 |
| SUBPLOT: | | | | | | | | | |
| $F_4$ lines within $F_3$ families | 64 | ........... | 19.51** | ........... | 16.60** | ........... | 18.33** | ........... | 32.06** |
| | 4 | 1415–22 | 18.23** | 2715–4 | 28.90** | 3515–3 | 4.90** | 3715–15 | 34.90** |
| | 4 | " –25 | 2.93 | " –17 | 18.00** | " –16 | 13.57** | " –18 | 47.60** |
| | 4 | " –29 | 9.50** | " –23 | 11.07** | " –18 | 2.07 | " –20 | 23.10** |
| | 4 | " –30 | 42.07** | " –30 | 2.17 | " –29 | 18.27** | " –23 | 2.40 |
| | 4 | " –32 | 18.00** | " –31 | 1.17 | " –37 | 4.90** | " –25 | 39.60** |
| | 4 | " –42 | 21.10** | " –38 | 38.43** | " –44 | 6.50** | " –26 | 18.50** |
| | 4 | " –44 | 12.50** | " –40 | 26.57** | " –51 | 3.40 | " –39 | 14.43** |
| | 4 | " –50 | 15.10** | " –51 | 19.43** | " –67 | 1.33 | " –48 | 2.27 |
| | 4 | " –56 | 14.77** | " –56 | 8.77** | " –68 | 96.33** | " –53 | 30.43** |
| | 4 | " –57 | 8.57** | " –58 | 18.77** | " –73 | 5.73** | " –68 | 145.43** |
| | 4 | " –60 | 13.40** | " –63 | 3.33* | " –82 | 13.43** | " –73 | 44.57** |
| | 4 | " –63 | 6.57** | " –72 | 19.07** | " –88 | 57.77** | " –76 | 10.00** |
| | 4 | " –72 | 26.57** | " –76 | 19.50** | " –93 | 10.67** | " –80 | 25.27** |
| | 4 | " –74 | 76.57** | " –78 | 22.23** | " –95 | 43.83** | " –83 | 47.67** |
| | 4 | " –77 | 4.00* | " –80 | 7.33** | " –98 | 7.77** | " –96 | 0.67 |
| Parents and bulks | 4 | ........... | 22.33** | ........... | 20.83** | ........... | 10.77** | ........... | 26.07** |
| Error (b) | 128 | ........... | 1.54 | ........... | 1.10 | ........... | 1.40 | ........... | 1.50 |

*Significant at the 5 percent level. **Significant at the 1 percent level.

TABLE 39. MEAN LODGING SCORES OF $F_4$ LINES, PARENTS AND BULK GENERATIONS IN 1946 FOR CROSS 1415 (MUKDEN X RICHLAND) IN COMPARISON WITH MEAN LODGING SCORES OF PARENTAL $F_3$ LINES IN 1945.

| Cross and $F_2$ plant number | $F_3$ line (Lodging score) | $F_4$ lines (Lodging scores) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | Mean |
| 1415-22 | 2.3 | 1.3 | 2 0 | 2 0 | 1.0 | 1.7 | 1 6 |
| 1415-25 | 2.7 | 3.3 | 2.0 | 3.0 | 2.7 | 3 0 | 2.8 |
| 1415-29 | 2.7 | 2 3 | 2 0 | 2.7 | 2.0 | 2.3 | 2.3 |
| 1415-30 | 2 0 | 2.0 | 2 3 | 2.7 | 1.7 | 2.0 | 2.1 |
| 1415-32 | 2.3 | 1.7 | 1.0 | 2 0 | 2.7 | 1.3 | 1.7 |
| 1415-42 | 2 3 | 1.3 | 1 0 | 1.7 | 1.3 | 1.7 | 1.4 |
| 1415-44 | 2 7 | 2.3 | 1.7 | 3.3 | 3.3 | 2.3 | 2.6 |
| 1415-50 | 2.3 | 2 0 | 2.3 | 2.3 | 2.0 | 2.3 | 2.2 |
| 1415-56 | 2 3 | 2.0 | 2.7 | 2.3 | 1 7 | 2.7 | 2.3 |
| 1415-57 | 1 7 | 2.3 | 1.0 | 1.3 | 2.3 | 1.0 | 1.6 |
| 1415-60 | 2.3 | 2.0 | 2.0 | 2.7 | 1.7 | 1.3 | 1.9 |
| 1415-63 | 2 3 | 1.7 | 3.0 | 2.0 | 2.7 | 1.3 | 2.1 |
| 1415-72 | 1 7 | 2.0 | 2.0 | 2 0 | 1.7 | 2.0 | 1.9 |
| 1415-74 | 2.0 | 2.0 | 1.0 | 2.3 | 2.7 | 2 3 | 2.1 |
| 1415-77 | 1.3 | 1.3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |

| Mukden | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 2.7 | 1.3 | 2.3 | 2 7 | 2.0 |

Mean lodging score of all entries in 1946 test
2.0

TABLE 40. MEAN LODGING SCORES OF $F_4$ LINES, PARENTS AND BULK GENERATIONS IN 1946 FOR CROSS 2715 (MANCHURIA 13-177 X RICHLAND) IN COMPARISON WITH MEAN LODGING SCORES OF PARENTAL $F_3$ LINES IN 1945.

| Cross and $F_2$ plant number | $F_3$ line (Lodging score) | $F_4$ lines (Lodging scores) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | Mean |
| 2715-4 | 2.3 | 3.0 | 3 0 | 1 3 | 2.0 | 3.3 | 2.5 |
| 2715-17 | 2.7 | 1.3 | 1 0 | 1.0 | 1.3 | 2.3 | 1.4 |
| 2715-23 | 2.7 | 1 0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.6 |
| 2715-30 | 2.3 | 2.3 | 1.7 | 3.0 | 3.0 | 2.3 | 2.5 |
| 2715-31 | 3.0 | 3.0 | 3.0 | 2.7 | 2.7 | 3.0 | 2.9 |
| 2715-38 | 3 0 | 3 3 | 3.3 | 3.3 | 3.0 | 3.3 | 3 3 |
| 2715-40 | 2.3 | 1.7 | 1.3 | 2.7 | 2.0 | 2 0 | 1.9 |
| 2715-51 | 3.0 | 3.0 | 2.3 | 2 7 | 3.0 | 3.3 | 2.9 |
| 2715-56 | 3.0 | 1.3 | 2.0 | 1.7 | 2.7 | 2.0 | 1.9 |
| 2715-58 | 2.7 | 3.7 | 3.7 | 2.7 | 3.0 | 2.3 | 3.1 |
| 2715-63 | 3.0 | 3.0 | 3 0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 2715-72 | 2.0 | 1.7 | 2.0 | 3.0 | 2.3 | 3.0 | 2.4 |
| 2715-76 | 3.3 | 3.0 | 3.3 | 1.7 | 3.0 | 4.0 | 3.0 |
| 2715-78 | 2.7 | 2.7 | 3.0 | 2.7 | 1 7 | 3 0 | 2.6 |
| 2715-80 | 2.7 | 3.3 | 3.0 | 3.3 | 3.3 | 3.0 | 3.2 |

| Manchuria 13-177 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 4.0 | 1.3 | 3.0 | 3.7 | 3.3 |

Mean lodging score of all entries in 1946 test
2.6

TABLE 41. MEAN LODGING SCORES OF $F_4$ LINES, PARENTS AND BULK GENERATIONS IN 1946 FOR CROSS 3515 (P. I. 79885 X RICHLAND) IN COMPARISON WITH MEAN LODGING SCORES OF PARENTAL $F_3$ LINES IN 1945.

| Cross and $F_2$ plant number | $F_3$ line (Lodging score) | $F_4$ lines (Lodging scores) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | Mean |
| 3515–3 | 1.7 | 1.3 | 1.3 | 1.0 | 1.3 | 1.0 | 1.2 |
| 3515–16 | 2.7 | 1.3 | 2.3 | 2.3 | 1.3 | 2.7 | 2.0 |
| 3515–18 | 2.3 | 3.0 | 2.7 | 2.3 | 3.0 | 2.3 | 2.7 |
| 3515–29 | 3.0 | 1.0 | 1.7 | 2.7 | 1.3 | 1 0 | 1.5 |
| 3515–37 | 2.0 | 1.0 | 1.3 | 2.7 | 1.0 | 1.0 | 1.4 |
| 3515–44 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.2 |
| 3515–51 | 2.3 | 2.3 | 2.0 | 2.3 | 2.3 | 2.3 | 2.3 |
| 3515–67 | 1.7 | 2.3 | 2.3 | 1.3 | 1.7 | 2.0 | 1.9 |
| 3515–68 | 3.7 | 2.3 | 1.0 | 3.0 | 2.0 | 3.0 | 2.3 |
| 3515–73 | 2.3 | 1.0 | 2.0 | 1.7 | 1.3 | 2.7 | 1.7 |
| 3515–82 | 1.3 | 1.7 | 2.3 | 1.7 | 1.0 | 1.0 | 1.5 |
| 3515–88 | 2.7 | 2.0 | 3.0 | 2.7 | 2.7 | 1.3 | 2.3 |
| 3515–93 | 2.7 | 3.3 | 2.7 | 2.0 | 3.3 | 3.0 | 2.9 |
| 3515–95 | 2.0 | 1.3 | 2.7 | 3.0 | 2.0 | 1.3 | 2.1 |
| 3515–98 | 2.3 | 2.3 | 2.3 | 3.0 | 2.0 | 1.3 | 2.2 |

| P. I. 79885 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 2.7 | 1.3 | 2.0 | 2.7 | 2.3 |

Mean lodging score of all entries in 1946 test
2.0

TABLE 42. MEAN LODGING SCORES OF $F_4$ LINES, PARENTS AND BULK GENERATIONS IN 1946 FOR CROSS 3715 (P. I. 89009-2 X RICHLAND) IN COMPARISON WITH MEAN LODGING SCORES OF PARENTAL $F_3$ LINES IN 1945.

| Cross and $F_2$ plant number | $F_3$ line (Lodging score) | $F_4$ lines (Lodging scores) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | Mean |
| 3715–15 | 1.7 | 2.0 | 2.0 | 1.3 | 1.3 | 1.7 | 1.7 |
| 3715–18 | 2.7 | 2.7 | 3.0 | 3.0 | 1.3 | 3.0 | 2.6 |
| 3715–20 | 2.7 | 3.0 | 2.3 | 2.7 | 3.7 | 3.7 | 3.1 |
| 3715–23 | 2.7 | 1.3 | 1.3 | 2.0 | 2.0 | 2.3 | 1.8 |
| 3715–25 | 3.0 | 3.0 | 3.0 | 1.0 | 2.7 | 3.7 | 2.7 |
| 3715–26 | 3.3 | 3.0 | 3.0 | 3.7 | 2.7 | 1.3 | 2.7 |
| 3715–39 | 2.7 | 3.0 | 3.0 | 3.3 | 3.0 | 3.3 | 3.1 |
| 3715–48 | 2.3 | 3.0 | 2.7 | 3.3 | 4.0 | 3.3 | 3.3 |
| 3715–53 | 2.0 | 1.3 | 2.3 | 2.0 | 1.0 | 1.0 | 1.5 |
| 3715–68 | 2.3 | 1.0 | 2.3 | 2.3 | 1.0 | 2.7 | 1.9 |
| 3715–73 | 2 7 | 1.0 | 2.7 | 1.7 | 2.7 | 1.7 | 1.9 |
| 3715–76 | 2.7 | 1.0 | 2.7 | 1.0 | 1.0 | 1.0 | 1 3 |
| 3715–80 | 2.7 | 3.0 | 2.3 | 3.0 | 1.7 | 1.3 | 2.3 |
| 3715–83 | 2.0 | 1.3 | 1.0 | 1.3 | 1.0 | 2.7 | 1.5 |
| 3715–96 | 2.7 | 1.7 | 1.7 | 2.7 | 2.3 | 1.3 | 1.9 |

| P. I. 89009-2 | Richland | Bulk $F_3$ | Bulk $F_4$ | Bulk $F_5$ |
|---|---|---|---|---|
| 2.0 | 1.0 | 3.0 | 3.3 | 3.0 |

Mean lodging score of all entries in 1946 test
2.2

TABLE 43. ANALYSES OF VARIANCE OF LODGING SCORES OBTAINED IN 1946 TEST OF $F_4$ LINES, PARENTS AND BULK POPULATIONS IN EACH OF FOUR SOYBEAN CROSSES.

| Source of variation | D. F. | Mukden x Richland | | Manchuria 13-177 x Richland | | P. I. 79885 x Richland | | P. I. 89009-2 x Richland | |
|---|---|---|---|---|---|---|---|---|---|
| | | Cross and $F_4$ plant number | Mean square | Cross and $F_2$ plant number | Mean square | Cross and $F_2$ plant number | Mean square | Cross and $F_2$ plant number | Mean square |
| WHOLE PLOT: | | | | | | | | | |
| Replications | 2 | ........ | 7.33 | ........ | 0.99 | ........ | 8.79 | ........ | 4.41 |
| $F_3$ family progenies | 15 | ........ | 2.89** | ........ | 4.07** | ........ | 3.66** | ........ | 5.91** |
| Error (a) | 30 | ........ | 0.51 | ........ | 0.60 | ........ | 0.62 | ........ | 0.38 |
| SUBPLOT: | | | | | | | | | |
| $F_4$ lines within $F_3$ families | 64 | ........ | 0.72** | ........ | 1.06** | ........ | 1.01** | ........ | 1.42** |
| | 4 | 1415–22 | 0.57* | 2715–4 | 2.10** | 3515–3 | 0.10 | 3715–15 | 0.33 |
| | 4 | " –25 | 0.77* | " –17 | 0.90** | " –16 | 1.17** | " –18 | 1.57** |
| | 4 | " –29 | 0.23 | " –23 | 2.40** | " –18 | 0.33 | " –20 | 1.07** |
| | 4 | " –30 | 0.43 | " –30 | 0.93** | " –29 | 1.43** | " –23 | 0.60** |
| | 4 | " –32 | 1.23** | " –31 | 0.10 | " –37 | 1.57** | " –25 | 3.00** |
| | 4 | " –42 | 0.23 | " –38 | 0.07 | " –44 | 0.60** | " –26 | 2.23** |
| | 4 | " –44 | 1.57** | " –40 | 0.73** | " –51 | 0.07 | " –39 | 0.10 |
| | 4 | " –50 | 0.10 | " –51 | 0.43 | " –67 | 0.57* | " –48 | 0.73** |
| | 4 | " –56 | 0.57* | " –56 | 0.73** | " –68 | 2.07** | " –53 | 1.10** |
| | 4 | " –57 | 1.40** | " –58 | 1.07** | " –73 | 1.23** | " –68 | 1.93** |
| | 4 | " –60 | 0.73* | " –63 | 0.00 | " –82 | 0.93** | " –73 | 1.57** |
| | 4 | " –63 | 1.43** | " –72 | 1.07** | " –88 | 1.33** | " –76 | 1.67** |
| | 4 | " –72 | 0.07 | " –76 | 2.17** | " –93 | 0.93** | " –80 | 1.73** |
| | 4 | " –74 | 1.23** | " –78 | 0.90** | " –95 | 1.73** | " –83 | 1.43** |
| | 4 | " –77 | 0.07 | " –80 | 0.10 | " –98 | 1.10** | " –96 | 0.90** |
| Parents and bulks | 4 | | 0.93** | ........ | 3.23** | ........ | 0.93** | ........ | 2.77** |
| Error (b) | 128 | ........ | 0.23 | ........ | 0.18 | ........ | 0.17 | ........ | 0.15 |

*Significant at the 5 percent level.

**Significant at the 1 percent level.

TABLE 44. CORRELATION COEFFICIENTS BETWEEN GENERATIONS GROWN IN SUCCESSIVE YEARS FOR YIELDS, MATURITIES, HEIGHTS AND LODGING SCORES OF SEGREGATES IN EACH OF FOUR SOYBEAN CROSSES.

| Character and variates correlated | D. F. | Mukden x Richland (Cross 1415) | Manchuria 13-177 x Richland (Cross 2715) | P. I. 79885 x Richland (Cross 3515) | P. I. 89009-2 x Richland (Cross 3715) |
|---|---|---|---|---|---|
| SEED YIELD: | | | | | |
| $F_2$ plant and mean of $F_4$ lines | 13 | .26 | .35 | —.65** | —.01 |
| $F_3$ plant and $F_4$ line | 73 | .30** | | | |
| $F_3$ line and mean of $F_4$ lines | 13 | .46 | .04 | —.03 | .08 |
| MATURITY: | | | | | |
| $F_2$ plant and mean of $F_4$ lines | 13 | .74** | .81** | .79** | .32 |
| $F_3$ plant and $F_4$ line | 73 | .74** | | | |
| $F_3$ line and mean of $F_4$ lines | 13 | .35 | .92** | .92** | .37 |
| HEIGHT: | | | | | |
| $F_2$ plant and mean of $F_4$ lines | 13 | .42 | .61* | .72** | .14 |
| $F_3$ plant and $F_4$ line | 73 | .85** | | | |
| $F_3$ line and mean of $F_4$ lines | 13 | .85** | .61* | .84** | .49 |
| LODGING SCORE: | | | | | |
| $F_3$ line and mean of $F_4$ lines | 13 | .71** | .39 | .46 | .44 |

*P less than 0.05. ** P less than 0.01.

close to zero, indicating almost a complete lack of association for yield between these generations. If this lack of relationship were true for soybean crosses in general, selection for yield on the basis of pedigree yield tests in the $F_3$ generation would certainly be of doubtful value in the breeding program.

A number of the correlations for maturity and height in table 44 were statistically significant. All of them were positive. Maturity and height measurements on $F_2$ plants and their replicated progeny rows in the $F_3$ generation, therefore, were of value in predicting results in the succeeding generation of these crosses. Only one of the crosses showed a significant correlation for lodging score between the $F_3$ and $F_4$ generations. Consequently, selection for lodging resistance on the basis of $F_3$ data would have been less effective than selection for differences in maturity and height.

## CHARACTER RELATIONSHIPS

The main objective of most soybean breeding programs is the development of adapted, high yielding, lodging resistant varieties, tall enough to harvest with a combine. The extent of relationships between maturity, height, lodging resistance and yield in segregating populations of soybean crosses may definitely influence the realization of this objective.

In the pedigree phase of this study correlations were used to measure the degree of association between agronomic characters in the $F_2$, $F_3$ and $F_4$ generations of each cross. As shown in table 45, all correlations between maturity and height were positive and highly significant in every generation of each cross, irrespective of differences in yield. All simple correlations between maturity and yield and height and yield of the $F_2$ plants also were positive and highly significant. Partial correlations for the same characters were, in most instances, considerably lower, as were the simple correlations for the $F_3$ and $F_4$ generations. In the majority of cases the partial correlations between maturity and yield and height and yield in the $F_3$ and $F_4$ generations were smaller than the corresponding simple correlations. Correlations between lodging and yield all were positive but only one was highly significant and another significant. The results indicated that the most consistent association occurred between maturity and height.

The nature of these relationships has a bearing on the attainment of soybean breeding objectives. The strong positive association between maturity and height emphasized the difficulty of securing desired tall early segregates in these populations. As the taller plants and lines tended to yield more, selection for tallness favored selection for yield. Early maturity, on the other hand, was not associated with high yield. There also was a tendency for the most lodging resistant lines to yield less. Character relationships, there-

TABLE 45. SIMPLE AND PARTIAL CORRELATION COEFFICIENTS BETWEEN AGRONOMIC CHARACTERS OF 100 $F_2$ PLANTS, 77 $F_3$ LINES AND 75 $F_4$ LINES IN EACH OF FOUR SOYBEAN CROSSES.

| Characters correlated | Mukden x Richland (Cross 1415) | | | Manchuria 13-177 x Richland (Cross 2715) | | | P. I. 79885 x Richland (Cross 3515) | | | P. I. 89009-2 x Richland (Cross 3715) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $F_2$ 1944 | $F_3$ 1945 | $F_4$ 1946 | $F_2$ 1944 | $F_3$ 1945 | $F_4$ 1946 | $F_2$ 1944 | $F_3$ 1945 | $F_4$ 1946 | $F_2$ 1944 | $F_3$ 1945 | $F_4$ 1946 |
| Maturity (m) and height (h) | | | | | | | | | | | | |
| $r_{mh}$ | .74 | .57 | .51 | .76 | .79 | .78 | .61 | .38 | .44 | .56 | .51 | .50 |
| $r_{mh.y}$ | .67 | .54 | .48 | .63 | .80 | .79 | .42 | .40 | .45 | .40 | .51 | .54 |
| Maturity (m) and yield (y) | | | | | | | | | | | | |
| $r_{my}$ | .49 | .39 | .23 | .56 | .04 | .00 | .58 | .34 | —.10 | .48 | .13 | .50 |
| $r_{my.h}$ | .29 | .32 | .11 | .16 | —.15 | —.12 | .36 | .37 | —.14 | .24 | .07 | .53 |
| Height (h) and yield (y) | | | | | | | | | | | | |
| $r_{hy}$ | .42 | .23 | .27 | .63 | .17 | .10 | .56 | —.01 | .06 | .57 | .14 | .07 |
| $r_{hy.m}$ | .11 | .11 | .19 | .38 | .22 | .15 | .32 | —.15 | .12 | .41 | .08 | —.24 |
| Lodging score (l) and yield (y) | | | | | | | | | | | | |
| $r_{ly}$ | ....... | .21 | .36 | ....... | .09 | .13 | ....... | .25 | .13 | ....... | .16 | .09 |

Correlation coefficients at the 5% and 1% levels of significance

| | $F_2$ | $F_3$ | $F_4$ |
|---|---|---|---|
| 5% | .197 | .225 | .228 |
| 1% | .257 | .293 | .296 |

fore, affected selection potentialities to varying degrees in the segregating populations of the crosses included in this study.

## DISCUSSION

Hybridization followed by selection in segregating populations is the most promising method of obtaining new and improved varieties of soybeans. Several outstanding soybean varieties have been developed by this breeding procedure and many promising selections from crosses are now in the early stages of testing in regional trials. Despite this evidence of success, however, there are disturbing features about the use of hybridization in soybean improvement that need clarification. A large number of crosses between varieties and strains of this crop have failed to produce desirable recombinations in the resulting segregates. Although many of these crosses apparently have shown transgressive segregation in the $F_2$ and $F_3$ generations for factors conditioning various important characters, only a very few have given any promising new types after subsequent selection. Such results have led to considerable confusion.

Several possible reasons can be postulated for this apparent failure to obtain or detect improved segregates in many soybean crosses. First of all, as soybean breeding is a comparatively recent development, there has been little opportunity to evaluate varieties as parental material in crosses. Consequently, many crosses have been made which probably would not have been made had such information been available. Moreover, a number of these crosses were made between related types, and as a result, the potentialities for new recombinations were decreased. Another reason lies in the methods used to evaluate crosses in the generations following hybridization. Soybean breeders, in general, have utilized the same procedures for handling segregating populations of crosses as those employed by breeders of the self-pollinated cereals. Soybean varieties, however, are considerably more responsive to environmental fluctuations, especially changes in photoperiod, than small grain varieties. In addition, soybeans are a full-season crop, and hence response to variations in climate includes a greater time factor than in small grains. Consequently, soybean strains frequently react differentially in two localities even though soil, temperature and rainfall conditions may be similar. Selection for differences among segregates in one locality or year, therefore, may not insure similar performance in another locality or year. Because of these factors, it is conceivable that segregating populations of soybean crosses may not be as well adapted as is commonly supposed to breeding methods used with cereals. This might pertain especially to the methods used for early generation testing in small grain crosses.

Immer (11) attempted to relate the average yield performance of spaced $F_1$ plants in several barley crosses with that of their bulk populations in drilled plots in subsequent generations. He noted a considerable lack of agreement between the yields of the $F_1$ and subsequent generations. A similar lack of agreement between the extent of heterosis for seed yields in the $F_1$ and succeeding generations in a number of soybean crosses was found by Weiss, Weber and Kalton (27). Both reports stressed the impracticability of making such $F_1$ yield studies, primarily because of the limited supplies of crossed seed. The conclusions from $F_1$ generation results reported herein agreed very well with previous investigations. Mukden x Richland, the cross which showed the least superiority over the common parent in $F_1$ spaced plant tests, was the highest yielding of the four crosses in replicated trials of the bulk $F_2$ to $F_4$ populations. Two other crosses were considerably above the common parent in seed yield in the $F_1$ generation but no better than it in bulk tests of succeeding generations. A similar lack of association was noted between $F_1$ yields and mean yields of 77 randomly selected $F_3$ lines in each cross. Little or no information about the yielding potentialities of the four crosses was gained, therefore, by measuring seed yields on spaced $F_1$ plants.

In addition to seed yield, height and maturity differences among the four crosses were evaluated in the $F_1$ generation in comparison to Richland. Although based on only a few $F_1$ plants per cross, these comparisons were of considerable interest when examined in light of the advanced generation performance of the crosses for the same characters. In the $F_1$ generation Manchuria 13-177 x Richland and P. I. 89009-2 x Richland were the latest of the crosses, as compared to the maturity of Richland. P. I. 79885 x Richland, on the other hand, was the earliest of the crosses in the same respect. These average maturity differences among the crosses remained quite consistent in all subsequent generations. The average height differences among the crosses in the $F_1$ generation, as compared to Richland, also persisted in later generations. Only one of the crosses, namely, P. I. 89009-2 x Richland, exceeded both parents in average plant height in the $F_1$ generation. Moreover, this average height superiority was retained in both bulk and pedigree tests of the $F_2$ to $F_4$ generations. Evidently this cross resulted in a combination of complementary genes for plant height. The $F_1$ generation results for plant height and date of maturity, therefore, were indicative of average differences among the crosses for these characters in advanced generations.

One of the principal disadvantages of bulk population trials of soybean crosses is the inability to obtain much information on the extent of segregation for factors conditioning height, maturity, lodging resistance and yield, as such tests give only average performance records. As an example, Manchuria 13-177 x Richland was one of the latest and tallest of the crosses in the bulk population trials, yet it produced a number of short and early $F_2$ plants and $F_3$ lines. Similar contrasts were apparent in the other crosses. Consequently, although the bulk populations of all crosses performed quite consistently for mean maturity, height and lodging resistance at successive generations in consecutive years, the results were of limited value in determining the range of selection potentialities for these characters in each of the crosses. This was especially evident for such a character as early maturity. On the other hand, average differences among the bulk populations of the crosses did provide some information on intercross selection opportunities for increased height and lodging resistance.

Harlan, Martini and Stevens (5) and Harrington (7) successfully used early generation tests of bulk populations of barley and wheat crosses, respectively, to detect potentially low-yielding crosses. A similar study of the early generation yield performance of 17 soybean crosses, reported by Weiss, Weber and Kalton (27), was of little value for predicting the yielding ability of selected segregates. In the same investigation considerable disagreement was found between bulk population yields of different generations, whether grown the same year or in different years. As a result, the inconsistencies observed herein in the bulk population yields of 25 soybean crosses at successive generations were not entirely unexpected. Yield differences among bulk populations of the crosses in $F_2$ were not very well substantiated by similar tests of the $F_3$ and $F_4$ generations in succeeding years. A considerable proportion of these erratic yield results probably was due to differences in competitive ability both among and within crosses as a consequence of differential segregation for factors conditioning maturity, height, lodging resistance and possibly even yield. The selective action of early and late fall frosts also may affect bulk populations of different crosses in a diverse manner. In contrast, bulk populations of small grain crosses usually do not exhibit such extreme variability for the same characters, nor does frost damage become a factor during the reproductive stages. It seems probable, therefore, that early generation testing of bulk populations of crosses in soybeans will not be as practical from a breeding standpoint as similar tests of small grain crosses.

One of the more controversial questions confronting soybean breeders is whether or not to space-plant segregating populations of crosses to facilitate plant selection. This problem is of greatest significance in $F_2$ and $F_3$ when opportunities for selection are greatest. Close planting (1- to 3-inch spacing of plants in the row) generally puts the earlier and shorter $F_2$ and $F_3$ plants at a serious competitive disadvantage and tends to favor the taller and later segregates. A wider spacing (6- to 12-inch spacing of plants in the row) helps overcome these disadvantages. At the same time, however, space-planting greatly increases the amount of soil heterogeneity and also causes the individual plants to branch more and grow shorter than usual. Consequently, either wide or narrow spacings of plants within the row may interfere with the expression of genetic differences among $F_2$ and $F_3$ plants of a cross.

An attempt was made in the pedigree phase of this investigation to determine the value of selection for differences in agronomic characters among spaced $F_2$ and $F_3$ plants of four soybean crosses. Nonreplicated plantings were used so that conditions would conform to general practice. Seed yield, maturity and plant height varied considerably not only among the $F_2$ plants of each cross but also among the plants of several pure breeding parental varieties. As was expected because of genetic segregation, the extent of variation for each character among the $F_2$ plants generally was greater for the crosses than for the varieties. The crosses, however, differed quite markedly in this respect. A better measure of the agronomic differences among $F_2$ plants in each cross was obtained by growing a replicated test of their progenies in $F_3$. In all but one case the mean agronomic differences among $F_3$ lines in each cross were highly significant when analyzed statistically. Moreover, differences in maturity and plant height among $F_3$ lines were strongly associated with parental $F_2$ plant differences in the previous year. There was, however, little indication of a significant regression of mean yields of $F_3$ lines on parental $F_2$ plant yields. Similar results were obtained for one of the crosses when agronomic measurements of spaced $F_3$ plants were correlated with their $F_4$ line means.

Yield distributions of $F_3$ lines in each cross were sampled to continue the study in $F_4$. Each $F_3$ line thus selected was represented in the $F_4$ generation by replicated progenies of five of its constituent $F_3$ plants. Results of this $F_4$ line test indicated that little homozygosity existed in $F_3$ for factors conditioning maturity, plant height and lodging resistance. In most cases there were highly significant differences among $F_4$ lines within $F_3$ families for each of these characters. $F_3$ family progeny means in each cross also differed significantly for the same characters. Furthermore, the $F_4$ generation results for maturity, height and lodging resistance were reasonably associated with the previous performance of the respective parental $F_2$ plants and $F_3$ lines. On the basis of this observed breeding behavior, intensive selection for differences in plant height and maturity among spaced $F_2$ plants and their space-planted $F_3$ progeny rows appears justified as a breeding procedure.

Mean yields of $F_3$ family progenies in $F_4$ apparently regressed toward the cross means, as only one of the crosses showed significant differences among the means of the $F_3$ family progenies. Yields of neither parental $F_2$ plants nor parental $F_3$ lines were associated in a significantly positive manner with mean yields of their $F_3$ family progenies in the $F_4$ line test. Mean yield differences among $F_3$ lines, therefore, were not substantiated by the results in the succeeding generation. Weiss, Weber and Kalton (27) likewise found a lack of desirable association between mean yields of pedigree lines in $F_3$

and their descendant progenies in $F_4$. However, they encountered two widely diverse seasons during their study. All investigations reported herein were conducted during reasonably normal seasons. Consequently, on the basis of these two similar studies, it would seem that neither the bulk nor the pedigree method of early generation testing in soybean crosses provides much information, at least before the $F_4$ generation, on the potential yielding ability of subsequent selections.

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